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Radian Corp., Austin, TX

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SOLVENT RECOVERY AT VANDENBERG AIR FORCE BASE

By

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EPA Contract 68-02-3171, Task 81

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16. ABSTRACT The report gives results of a feasibility study of the addition of vapor recovery and solvent purification equipment for Vandenberg Air Force Base (VAFB) to reuse the large quantities of waste solvent generated in space shuttle preparation operations. (NOTE: Operation of VAFB as the western launch site for the shuttle will increase the volume of solvent waste generated.) This project included four major tasks: development of (1) design criteria, (2) a conceptual design, (3) a site layout and solvent logistics plan, and (4) detailed system design specifications. It was determined that vapor recovery can be justified at only one location, and that Freon-113 is the only solvent that can be economically purified for reuse. The final system design calls for a carbon adsorption unit for recovery of solvent vapors from the component cleaning facility (CCF) and a solvent purification facility that includes a water-wash column, two fractional distillation columns, molecular sieve driers, and two-stage filtration. Both facilities should be adjacent to the CCF, and a bulk Freon system should be installed for the CCF to reduce the handling of containerized solvents.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Spacecraft Launching Sites		22D
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Carbon		07B

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EXECUTIVE SUMMARY

When Vandenberg Air Force Base is fully operational as a launch site for the space shuttle, the generation of solvent wastes will increase by an order of magnitude over current levels. This report presents the results of a study to determine whether or not it is economically feasible to recover some of that solvent waste on-site, as well as the design for the system required to accomplish that solvent recovery.

Waste solvents will be produced by a variety of shuttle-related and non-shuttle-related processes on Vandenberg. Some of these processes are strongly influenced by the shuttle launch rate, while others are totally independent of it. All available data concerning the projected rates of waste solvent generation have been combined into a computational data base which is keyed to the launch rate. Preparation of this data base has been a significant part of this study, since both the economics and the design of a solvent recovery system depend on these data.

The latest figures indicate that waste solvent generation will exceed 70,000 gallons per year by 1995, based on attaining a rate of 9 launches per year by that time. The solvent Freon-113 is by far the largest component in the projected solvent waste, with an estimated concentration of 64 volume percent. The next most concentrated solvent species is methylene chloride, which is present at only 6.2 volume percent. It was determined that all other solvent species could not be economically recovered in the preliminary economic evaluations. Conceptual designs were developed for two purification facilities, one to recover only Freon and one to recover both Freon and methylene chloride. After evaluating the cost of these two systems and their respective savings in solvent costs, it was determined that there was no economic incentive to recover the methylene chloride at the low levels present in the composite solvent waste feed.

The use of solvent vapor recovery units was also considered for each existing, or planned, solvent use area at Vandenberg. The preliminary economic analysis eliminated all but two areas: the component cleaning facility and the SCAPE suit cleaning facility. The preliminary analysis for the SCAPE suit cleaning facility was based on the use of a process similar to the existing unit at Kennedy Space Center, but it was later learned that the unit planned for Vandenberg would probably use different technology (either a non-Freon type of cleaning or Freon-based cleaning in an enclosed unit with its own integral vapor recovery/solvent purification apparatus). As a result of

this, vapor recovery facilities were found to be warranted only for the component cleaning facility.

The recommended system consists of a carbon adsorption unit to recover Freon vapors from the component cleaning facility and a purification unit to upgrade the Freon in the liquid waste solvent stream to meet Type I military specifications. The purification unit includes a water-wash column, two fractional distillation columns, a molecular sieve dehydrator, and a two-stage filter (plus an assortment of tanks, heat exchangers, and piping necessary to integrate the major components). A microprocessor-based control system is also provided to improve quality control and to minimize the needs for operator intervention/sophistication.

It is recommended that both the vapor recovery and the purification units be located adjacent to, or inside of, the ultimate site of the component cleaning facility. This would allow the installation of a bulk Freon-113 handling system for the component cleaning facility, which is projected to be by far the largest user of the solvent. It would also allow flexibility in allocating manpower requirements between these compatible operations, as well as the sharing of utility systems.

The use of a bulk system at the component cleaning facility will greatly reduce the need for handling drums of spent and reclaimed solvent. This is highly beneficial in limiting labor costs and in reducing worker exposure to the potentially hazardous solvent waste. The few spent solvent streams from other use areas that are suitable for Freon recovery will be handled as a special disposition under the existing Hazardous Waste Management Plan at Vandenberg.

The installed capital cost of the purification system is estimated to be $795,000, while the cost of the vapor recovery unit is estimated to be $330,000. It has been assumed that that total investment of $1,125,000 in solvent recovery equipment would be financed with an interest rate similar to that currently paid on Treasury Bonds (about 11.75 %). The gross savings in solvent costs over the ten year project life using a fresh Freon price of $9.74 per gallon, and deducting $1.90 per gallon for the loss of offsite recovery potential, is in excess of $3,720,000. Assuming a ten year economic life cycle and using the Treasury Bond interest rate as the discount factor, the net present value of the investment in solvent recovery equipment is $118,550 (expressed in contant-value 1983 dollars). If a five percent general inflation rate is added to the calculation, the net present value of the investment increases to about $530,000. That is equivalent to an internal rate of

return of 19.45 %, or a simple payback period of about 5.3 years.

More recent information has been received which indicates that the launch rate may peak at about four launches per year and that the full activation of ground support facilities may be delayed until 1989. Although this information arrived too late to be incorporated in the main design and economic calculations for this study, some estimates were made of the probable impact of these changes on the economic viability of the solvent recovery project. The reduction in launch rate, and the corresponding reduction in waste solvent generation rates, decreases the potential gross savings. That effect is more than offset, however, by the delay in system construction, since the marginal years of operation (with only one or two launches) are eliminated. The preliminary calculations indicate that the net present value of the project would be $637,850, which corresponds to a 21.6% return on investment. These figures are based on a ten-year project life (1989 to 1998), a total of 39 launches (3 in 1989 and 4 in each of the remaining years), a general inflation rate of 5%, and a discount rate of 11.75%.

The construction of onsite solvent recovery facilities will create several benefits in addition to the economic incentives. Although no existing environmental regulations would force Vandenberg to control the atmospheric emissions of Freon-113, the compound is under study in the US EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP's) program, and could require control as a hazardous air pollutant in the future. It should be noted that aerosol propellant uses of the halocarbons have already been prohibited. Onsite recycling/reuse of this large component of the liquid solvent waste is also very much in line with the policies expressed in California's recent Executive Order to strictly limit any land disposal of organic wastes. Investment in the solvent recovery project will result in a hedge against future price increases for Freon and improved reliability of the supply for this vital solvent.

1.0 INTRODUCTION

This report presents the results of a study titled "Solvent Recovery at Vandenberg Air Force Base" which was performed under EPA Contract No. 68-02-3171/Work Assignment 81 through Interagency Agreement No. RW930153-01-1 with Air Force Systems Command, Space Division/Mission Assurance under the direction of Lt. Col. D. Downing and Lt. E. Hagan, assisted by Sherwin Lewis and Roberta F. Gleiter of The Aerospace Corporation. The primary objectives of this study were to determine whether or not solvent recovery is economically attractive at Vandenberg Air Force Base (VAFB) and (if so) to design a system to accomplish that recovery. The task breakdown for the effort included the development of design criteria, development of a conceptual design, development of recommendations on the system layout and solvent logistics, and the development of system design specifications. The solvent recovery technologies examined included carbon adsorption and condensation for solvent vapor recovery and a purification system based on various combinations of fractional distillation, water-washing, filtration, and dehydration.

The first step in this study was the development of design criteria for the solvent recovery system. The criteria are divided into two groups - minimum acceptable design criteria and prioritizing design criteria. The minimum acceptable criteria include:

1. The system must have a positive net present value (NPV) over its ten year economic life with a discount factor set at the Treasury Bond interest rate.

2. The system must produce recovered solvents that meet military specifications for fresh solvents.

3. Any unrecoverable solvent must be in a form to allow either disposal or offsite recovery by DPDO.

4. The selected system must meet all currently applicable environmental regulations.

5. The system must be designed to ensure worker health and safety.

6. The system must be able to start up by October, 1985.

7. The selected system must consist of demonstrated technology with proven reliability in similar solvent recovery operations.

The above criteria must be met by any candidate system, and therefore, cannot be used to prioritize acceptable candidates. The following criteria will be used in selecting the recommended system:

1. The system with the highest NPV will be recommended, if all other criteria are roughly equivalent.

2. The system requiring the lowest capital investment will be preferred if the NPV's are equal.

3. A high degree of system automation (which requires a minimum of operator intervention/sophistication) is desirable.

4. The selected system should be compatible with current/ planned waste capture, collection, and handling procedures.

5. The system should recover and purify as much of the solvent waste as is economically feasible.

6. The system should be able to process the full range of waste solvents projected for VAFB.

7. It would be desirable for the system to operate on utilities that are currently available or are already planned for installation at VAFB.

8. The system should recover as much solvent vapor from the use areas as is economically feasible.

The above criteria are applied to the various vapor recovery and solvent purification options in the conceptual design sections of this report.

All of the data presented in this report are based on a launch rate schedule transmitted to Radian by Aerospace Corporation in the letter dated October 7, 1983. Many of the waste solvent stream generation rates are significantly affected by the launch rate, and because of that, the system economics are launch-rate dependent. The launch scenario used in this report is based on the best estimates available at the time of writing (and is hopefully on the conservatively low side), but any refinements in the launch rate estimates should be

considered in the final decision on the solvent recovery investment.

Several abbreviations and short-hand notations have been used throughout this report. The primary solvent of interest has been referred to simply as "Freon", which is short for "Freon-113", which itself is merely one brand-name of the compound 1,1,2-1,2,2 trichlorotrifluoroethane. Most abbreviations are defined on first use and again in the larger tables.

Section 2 presents the projected solvent inventory on which the system design is based. Section 3 presents the assumptions, calculations, and specific results of the purification system conceptual design. Section 4 presents similar information for the vapor recovery system. Section 5 presents an economic analysis of the combined vapor recovery and solvent purification system, as well as the design specifications for the recommended system. Section 6 presents a discussion of the optimum location for the solvent recovery facilities at VAFB and of the logistics of fresh/spent solvent distribution.

2.0 PROJECTED INVENTORY OF WASTE LIQUID SOLVENTS

The projected solvent inventory for Vandenberg Air Force Base (VAFB) for the years 1986 through 1995 is presented in Table 2-1. This inventory includes both solvents associated with the shuttle preparation activities and solvents associated with other VAFB activities. The primary source of data for the solvent inventory is the draft report titled "Solvent Recycling Study for Vandenberg Air Force Base--Phase I. Used Solvent Inventory" by H.L. Lundblad of Aerospace Corporation and dated May 1983. The non-shuttle related solvent projections were updated in a letter from H.L. Lundblad to G.E. Harris dated August 3, 1983, and are based on prior work by Space Division contractors. Some shuttle related solvent use data were also revised in a letter from H.L. Lundblad to G.E. Harris dated January 10, 1984, and are the result of a NASA review of the VAFB projected waste inventory.

Each solvent waste stream in Table 2-1 is assigned an identification code. The first letter of that code designates the area of the base (and/or the type of activity) from which the waste solvent stream originates, and the codes are assigned as follows:

A - Orbiter Maintenance
B - Launch Pad
C - Solid Rocket Booster Refurbishment and Subassembly
D - Solid Rocket Booster Retrieval and Disassembly
E - External Tank Processing
F - SCAPE Suit Maintenance
G - Component Cleaning
H - Miscellaneous Shuttle Support Operations
I - Miscellaneous Non-Shuttle Support Operations
J - Space Launch Complex (SLC) 2, (Delta)
K - Atlas and Titan Launch Operations.

The one or two digits following the letter are a sequential numerical identification code for each stream generated within the area (or activity).

Table 2-2 presents a summary of the projected solvent inventory broken down into all known components down to the 0.1 volume percent level. This data includes all of the waste liquid solvents available for purification/recovery. In Section 3, each waste solvent stream is reviewed to determine its suitability for purification, and a table similar to Table 2-2 is presented for the total of all solvent streams proposed for purification. The potential for recovery of additional solvents through vapor recovery is explored in Section 4.

TABLE 2-1.

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GE[illegible]TION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
CLEANING OF WATER	A1	TOTAL	60	120	120	180	240	300	360	420	480	540	2820
PROOFING SPRAY		WATER	57	114	114	171	228	285	342	399	456	513	2679
GUNS FOR TILE		111TCEA	1	2	2	4	5	6	7	8	10	11	56
PREPARATION		FREON	1	1	1	2	2	3	4	4	5	5	28
		ETH ACETA	1	1	1	2	2	3	4	4	5	5	28
		ACETONE	1	1	1	2	2	3	4	4	5	5	28
SUBTOTAL STREAM GROUP "A"			60	120	120	180	240	300	360	420	480	540	2820
CLEANING OF WATER	B1	TOTAL	10	20	20	30	40	50	60	70	80	90	470
PROOFING SPRAY		WATER	10	19	19	29	38	48	57	67	76	86	447
GUNS FOR TILE		111TCEA	0	0	0	1	1	1	1	1	2	2	9
PREPARATION		FREON	0	0	0	0	0	1	1	1	1	1	5
		ETH ACETA	0	0	0	0	0	1	1	1	1	1	5
		ACETONE	0	0	0	0	0	1	1	1	1	1	5
STRUCTURAL	B2	TOTAL	330	660	660	990	1320	1650	1980	2310	2640	2970	15510
PAINTING		MIBK	7	13	13	20	26	33	40	46	53	59	310
CLEAN-UP		TOLUENE	7	13	13	20	26	33	40	46	53	59	310
		MEK	231	462	462	693	924	1155	1386	1617	1848	2079	10857
		EGMBE	3	7	7	10	13	17	20	23	26	30	155
		SOLIDS	83	165	165	248	330	413	495	578	660	743	3878
REMOVING INK FROM	B3	TOTAL	25	25	25	25	25	25	25	25	25	25	250
COMPUTER		FREON	25	25	25	25	25	25	25	25	25	25	245
DISK CASINGS		IC30H	0	0	0	0	0	0	0	0	0	0	3
		INK	0	0	0	0	0	0	0	0	0	0	3
SUBTOTAL STREAM GROUP "B"			365	705	705	1045	1385	1725	2065	2405	2745	3085	16230

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------->			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
APPLICATION OF BOSTIC, PRIMER, AND TOPCOAT TO SRB COMPONENTS	C1	TOTAL	50	100	100	150	200	250	300	350	400	450	2350
		AROMATICS	10	20	20	30	40	50	60	70	80	90	470
		MEK	10	20	20	30	40	50	60	70	80	90	470
		CHROMIUM	5	10	10	15	20	25	30	35	40	45	235
		GLYCOL ET	5	10	10	15	20	25	30	35	40	45	235
		ALCOHOLS	10	20	20	30	40	50	60	70	80	90	470
		CELL ACET	5	10	10	15	20	25	30	35	40	45	235
		AMINES	5	10	10	15	20	25	30	35	40	45	235
APPLICATION OF THERMAL PROTECTION TO SRB (WET MSA)	C2	TOTAL	1100	2200	2200	3300	4400	5500	6600	7700	8800	9900	51700
		ME CL	495	990	990	1485	1980	2475	2970	3465	3960	4455	23265
		PERC	495	990	990	1485	1980	2475	2970	3465	3960	4455	23265
		ETHANOL	88	176	176	264	352	440	528	616	704	792	4136
		ME DIANIL	11	22	22	33	44	55	66	77	88	99	517
		SOLIDS	11	22	22	33	44	55	66	77	88	99	517
APPLICATION OF EXTERIOR PAINT TO SRB'S	C3	TOTAL	40	80	80	120	160	200	240	280	320	360	1880
		111TCEA	20	40	40	59	79	99	119	139	158	178	931
		PERC	20	40	40	59	79	99	119	139	158	178	931
		SOLIDS	0	1	1	1	2	2	2	3	3	4	19
CLEANING OF SRB PARTS	C4	TOTAL	20	40	40	60	80	100	120	140	160	180	940
		111TCEA	20	39	39	59	78	98	118	137	157	176	921
		FREON	0	0	0	1	1	1	1	1	2	2	9
		GREASE	0	0	0	0	0	1	1	1	1	1	5
		DIRT	0	0	0	0	0	1	1	1	1	1	5

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
CLEANING OF SRB PARTS	C5	TOTAL	30	60	60	90	120	150	180	210	240	270	1410
		111TCEA	12	24	24	36	48	60	72	84	96	108	564
		MEK	12	24	24	36	48	60	72	84	96	108	564
		FREON	3	6	6	9	12	15	18	21	24	27	141
		ME CL	3	6	6	9	12	15	18	21	24	27	
PAINT STRIPPING OF SRB PARTS	C6	TOTAL	40	80	80	120	160	200	240	280	320	360	1880
		ME CL	26	52	52	78	104	130	156	182	208	234	1222
		CRES ACID	14	27	27	41	54	68	82	95	109	122	639
		SOLIDS	0	1	1	1	2	2	2	3	3	4	19
DEGREASING WITH MIXED SOLVENTS	C7	TOTAL	25	50	50	75	100	125	150	175	200	225	1175
		FREON	5	10	10	15	20	25	30	35	40	45	235
		ME CL	5	10	10	15	20	25	30	35	40	45	235
		TRICH	5	10	10	15	20	25	30	35	40	45	235
		PERC	5	10	10	15	20	25	30	35	40	45	235
		OIL	5	10	10	15	20	25	30	35	40	45	235
SUBTOTAL STREAM GROUP "C"			1305	2610	2610	3915	5220	6525	7830	9135	10440	11745	61335

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------)			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
DEGREASING OF SRB PARTS	D1		NOT APPLICABLE TO VAFB										
PAINT STRIPPING OF SRB'S	D2	TOTAL	40	80	80	120	160	200	240	280	320	360	1880
		ME CL	21	42	42	62	83	104	125	146	166	187	978
		CRES ACID	14	28	28	42	56	70	84	98	112	126	658
		FORM ACID	5	10	10	14	19	24	29	34	38	43	226
		SOLIDS	0	1	1	1	2	2	2	3	3	4	19
PAINT STRIPPING OF SRB'S	D3	TOTAL	50	100	100	150	200	250	300	350	400	450	2350
		TURCO	3	5	5	8	10	13	15	18	20	23	118
		ME CL	25	50	50	75	100	125	150	175	200	225	1175
		ETHANOL	15	30	30	45	60	75	90	105	120	135	705
		CRES ACID	7	14	14	21	28	35	42	49	56	63	329
		SOLIDS	1	1	1	2	2	3	3	4	4	5	24
DEGREASING OF SRB PARTS	D4	TOTAL	15	30	30	45	60	75	90	105	120	135	705
		111TCEA	14	27	27	41	54	68	81	95	108	122	635
		FREON	1	2	2	2	3	4	5	5	6	7	35
		WATER	1	1	1	2	2	3	4	4	5	5	28
		OIL	0	0	0	0	1	1	1	1	1	1	7
DEGREASING OF SRB PARTS	D5	TOTAL	40	80	80	120	160	200	240	280	320	360	1880
		FREON	20	40	40	60	80	100	120	140	160	180	940
		OIL	20	40	40	60	80	100	120	140	160	180	940
SUBTOTAL STREAM GROUP "D"			145	290	290	435	580	725	870	1015	1160	1305	6815

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR--------->			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
PRIMING AND CURING OF THE EXTERNAL TANK	E1	TOTAL	40	80	80	120	160	200	240	280	320	360	1880
		FREON	8	16	16	24	32	40	48	56	64	72	376
		ME CL	8	16	16	24	32	40	48	56	64	72	376
		MEK	8	16	16	24	32	40	48	56	64	72	376
		MIBK	8	16	16	24	32	40	48	56	64	72	376
		XYLENE	2	3	3	5	6	8	10	11	13	14	75
		N-BUTANOL	2	3	3	5	6	8	10	11	13	14	75
		TOLUENE	2	3	3	5	6	8	10	11	13	14	75
		ACETONE	2	3	3	5	6	8	10	11	13	14	75
		CYHEXONE	2	3	3	5	6	8	10	11	13	14	75
SUBTOTAL STREAM GROUP "E"			40	80	80	120	160	200	240	280	320	360	1880
SCAPE SUIT CLEANING	F1	TOTAL	10	20	20	30	40	50	60	70	80	90	470
		FREON	10	20	20	30	40	50	60	70	80	90	470
		IC3OH	0	0	0	0	0	0	0	0	0	0	0
		SOLIDS	0	0	0	0	0	0	0	0	0	0	0
SCAPE SUIT MAINTENANCE	F2	TOTAL	20	40	40	60	80	100	120	140	160	180	940
		TOLUENE	15	30	30	45	60	75	90	105	120	135	704
		FREON	5	10	10	15	20	25	30	35	40	45	234
		WATER	0	0	0	0	0	0	0	0	0	0	1
		MEK	0	0	0	0	0	0	0	0	0	0	1
SUBTOTAL STREAM GROUP "F"			30	60	60	90	120	150	180	210	240	270	1410

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------)			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
ALCOHOL REMOVAL FROM GAGES AND TRANSDUCERS	G1	TOTAL	500	1000	1000	1500	2000	2500	3000	3500	4000	4500	23500
		FREON	500	999	999	1499	1998	2498	2997	3497	3996	4496	23477
		IC3OH	1	1	1	2	2	3	3	4	4	5	24
GREASE REMOVAL FROM GAGES AND TRANSDUCERS	G2	TOTAL	10	20	20	30	40	50	60	70	80	90	470
		IC3OH	10	20	20	30	40	50	60	70	80	90	470
		GREASE	0	0	0	0	0	0	0	0	0	0	0
ULTRASONIC CLEANING OF INSTRUMENTS	G3	TOTAL	4	8	8	12	16	20	24	28	32	36	188
		FREON	1	3	3	4	5	7	8	10	11	12	64
		NAPHTHA	3	5	5	8	11	13	16	18	21	24	124
PRECISION OF PARTS AND ASSEMBLIES	G4	TOTAL	200	400	400	600	800	1000	1200	1400	1600	1800	9400
		FREON	196	392	392	588	784	980	1176	1372	1568	1764	9212
		IC3OH	4	8	8	12	16	20	24	28	32	36	188
COMPONENT CLEANING	G5	TOTAL	15	15	15	15	15	15	15	15	15	15	150
		FREON	14	14	14	14	14	14	14	14	14	14	140
		OIL	1	1	1	1	1	1	1	1	1	1	10
PAINT STRIPPING OF COMPONENTS	G6	TOTAL	20	40	40	60	80	100	120	140	160	180	940
		ME CL	12	24	24	36	48	60	72	84	96	108	564
		PHENOLICS	5	10	10	15	20	25	30	35	40	45	235
		CRES ACID	2	4	4	6	8	10	12	14	16	18	94
		DETERGENT	1	2	2	3	4	5	6	7	8	9	46
		SOLIDS	0	0	0	0	0	0	0	0	0	0	1

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
LAB ANALYSIS WASTE	G7	TOTAL	15	30	30	45	60	75	90	105	120	135	705
		IC3OH	2	5	5	7	9	11	14	16	18	20	106
		TOLUENE	2	5	5	7	9	11	14	16	18	20	106
		FREON	2	5	5	7	9	11	14	16	18	20	106
		MEK	1	1	1	2	2	3	4	4	5	5	28
		111TCEA	1	2	2	2	3	4	5	5	6	7	35
		TRICH	1	1	1	2	2	3	4	4	5	5	28
		XYLENE	1	1	1	2	2	3	4	4	5	5	28
		MIBK	1	1	1	2	2	3	4	4	5	5	28
		ME CL	1	1	1	2	2	3	4	4	5	5	28
		ACETONE	2	5	5	7	9	11	14	16	18	20	106
		HEXANE	2	5	5	7	9	11	14	16	18	20	106
LAB ANALYSIS WASTE	G8	TOTAL	100	200	200	300	400	500	600	700	800	900	4700
		FREON	15	30	30	45	60	75	90	105	120	135	705
		TOLUENE	4	8	8	12	16	20	24	28	32	36	188
		ACETONE	15	30	30	45	60	75	90	105	120	135	705
		MEK	15	30	30	45	60	75	90	105	120	135	705
		MIBK	15	30	30	45	60	75	90	105	120	135	705
		ME CL	15	30	30	45	60	75	90	105	120	135	705
		111TCEA	3	6	6	9	12	15	18	21	24	27	141
		IC3OH	15	30	30	45	60	75	90	105	120	135	705
		WATER	3	6	6	9	12	15	18	21	24	27	141

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
LAB ANALYSIS WASTE	G9	TOTAL	10	20	20	30	40	50	60	70	80	90	470
		FREON	10	20	20	30	40	50	59	69	79	89	465
		UNKNOWN	0	0	0	0	0	1	1	1	1	1	5
FREON RECOVERY STILL BOTTOMS	G10	NOT APPLICABL											
COMPONENT CLEANING "CLEAN ROOM"	G11	TOTAL	11914	20147	20147	24963	28380	31031	33196	35027	36613	38012	279430
		FREON	11866	20066	20066	24863	28267	30906	33063	34887	36467	37860	278312
		IC30H	48	81	81	100	114	124	133	140	146	152	1118
FIELD CLEANING OF "K" BOTTLES	G12	TOTAL	600	600	600	600	600	600	600	600	600	600	6000
		IC30H	570	570	570	570	570	570	570	570	570	570	5700
		PHOS ACID	30	30	30	30	30	30	30	30	30	30	300
SUBTOTAL STREAM GROUP "G"			13388	22480	22480	28155	32431	35941	38965	41655	44100	46358	325953
CLEANING HEAVY EQUIPMENT	H1	TOTAL	200	200	200	200	200	200	200	206	200	200	2000
		MIN SPIRT	140	140	140	140	140	140	140	140	140	140	1400
		ME CL	50	50	50	50	50	50	50	50	50	50	500
		PERC	10	10	10	10	10	10	10	10	10	10	100
SOLVENTS USED FOR PAINT CLEAN-UP	H2	TOTAL	300	300	300	300	300	300	300	300	300	300	3000
		MIBK	135	135	135	135	135	135	135	135	135	135	1350
		TOLUENE	135	135	135	135	135	135	135	135	135	135	1350
		XYLENE	15	15	15	15	15	15	15	15	15	15	150
		EGMBE	15	15	15	15	15	15	15	15	15	15	150

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------)			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
PAINT SHOP CLEAN-UP	H3	TOTAL	660	660	660	660	660	660	660	660	660	660	6600
		MEK	132	132	132	132	132	132	132	132	132	132	1320
		TOLUENE	99	99	99	99	99	99	99	99	99	99	990
		IC3OH	99	99	99	99	99	99	99	99	99	99	990
		SOLIDS	330	330	330	330	330	330	330	330	330	330	3300
PAINTING CLEAN-UP	H4	TOTAL	20	20	20	20	20	20	20	20	20	20	200
		UNKNOWN	10	10	10	10	10	10	10	10	10	10	100
		SOLIDS	10	10	10	10	10	10	10	10	10	10	100
PAINTING CLEAN-UP	H5	TOTAL	55	55	55	55	55	55	55	55	55	55	550
		NAPHTHA	19	19	19	19	19	19	19	19	19	19	187
		UNKNOWN	18	18	18	18	18	18	18	18	18	18	182
		SOLIDS	18	18	18	18	18	18	18	18	18	18	182
FABRICATION OF ELECTRICAL CABLE	H6	TOTAL	6	6	6	6	6	6	6	6	6	6	60
		MEK	6	6	6	6	6	6	6	6	6	6	59
		RAM 225	0	0	0	0	0	0	0	0	0	0	1
HEAVY EQUIPMENT PAINTING AND CLEAN-UP	H7	TOTAL	200	200	200	200	200	200	200	200	200	200	2000
		UNKNOWN	200	200	200	200	200	200	200	200	200	200	2000
CONTAMINATED POL SUMPS	H8	TOTAL	150	150	150	150	150	150	150	150	150	150	1500
		WATER	75	75	75	75	75	75	75	75	75	75	750
		UNKNOWN	75	75	75	75	75	75	75	75	75	75	750
PAINT STRIPPING OF HEAVY EQUIPMENT	H9	TOTAL	50	50	50	50	50	50	50	50	50	50	500
		UNKNOWN	50	50	50	50	50	50	50	50	50	50	500

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
FABRICATION OF	H10	TOTAL	300	300	300	300	300	300	300	300	300	300	3000
HOSES		FREON	294	294	294	294	294	294	294	294	294	294	2940
		OIL	3	3	3	3	3	3	3	3	3	3	30
		WATER	3	3	3	3	3	3	3	3	3	3	30
DEGREASING MOBILE	H11	TOTAL	50	50	50	50	50	50	50	50	50	50	500
EQUIPMENT		FREON	45	45	45	45	45	45	45	45	45	45	450
		IC3OH	3	3	3	3	3	3	3	3	3	3	25
		WATER	3	3	3	3	3	3	3	3	3	3	25
DEGREASING MOBILE	H12	TOTAL	50	50	50	50	50	50	50	50	50	50	500
EQUIPMENT		FREON	35	35	35	35	35	35	35	35	35	35	350
		WATER	13	13	13	13	13	13	13	13	13	13	125
		SOLIDS	2	2	2	2	2	2	2	2	2	2	20
		UNKNOWN	1	1	1	1	1	1	1	1	1	1	5
COMPRESSOR/CHILLER	H13	TOTAL	60	60	60	60	60	60	60	60	60	60	600
/GEARBOX		FREON-11	20	20	20	20	20	20	20	20	20	20	198
MAINTENANCE		KETONES	19	19	19	19	19	19	19	19	19	19	192
		ETH BENZ	19	19	19	19	19	19	19	19	19	19	192
		OIL	1	1	1	1	1	1	1	1	1	1	6
		GREASE	1	1	1	1	1	1	1	1	1	1	6
		SOLIDS	1	1	1	1	1	1	1	1	1	1	6
COMPRESSOR/CHILLER	H14	TOTAL	100	100	100	100	100	100	100	100	100	100	1000
/GEARBOX		FREON	99	99	99	99	99	99	99	99	99	99	990
MAINTENANCE		GREASE	1	1	1	1	1	1	1	1	1	1	10

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------)			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
GENERATOR MAINTENANCE	H15	TOTAL	150	150	150	150	150	150	150	150	150	150	1500
		FREON	38	38	38	38	38	38	38	38	38	38	375
		ME CL	38	38	38	38	38	38	38	38	38	38	375
		PERC	38	38	38	38	38	38	38	38	38	38	375
		111TCEA	36	36	36	36	36	36	36	36	36	36	360
		DIRT	2	2	2	2	2	2	2	2	2	2	15
AUTOMOBILE MAINTENANCE	H16	TOTAL	100	100	100	100	100	100	100	100	100	100	1000
		FREON	20	20	20	20	20	20	20	20	20	20	200
		ME CL	20	20	20	20	20	20	20	20	20	20	200
		PERC	20	20	20	20	20	20	20	20	20	20	200
		111TCEA	20	20	20	20	20	20	20	20	20	20	200
		CARB TET	20	20	20	20	20	20	20	20	20	20	200
MAINTENANCE OF ROADS AND GROUNDS	H17	TOTAL	110	110	110	110	110	110	110	110	110	110	1100
		MEK	75	75	75	75	75	75	75	75	75	75	750
		TOLUENE	2	2	2	2	2	2	2	2	2	2	20
		EGMBE	2	2	2	2	2	2	2	2	2	2	20
		MIBK	1	1	1	1	1	1	1	1	1	1	10
		SOLIDS	30	30	30	30	30	30	30	30	30	30	
EQUIPMENT TESTING	H18	TOTAL	100	100	100	100	100	100	100	100	100	100	1000
		OIL	95	95	95	95	95	95	95	95	95	95	950
		FREON	5	5	5	5	5	5	5	5	5	5	50

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO LAUNCHES PER YEAR---------)			1986 1	1987 2	1988 2	1989 3	1990 4	1991 5	1992 6	1993 7	1994 8	1995 9	TOTAL 47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
DEGREASING OF TEST EQUIPMENT	H19	TOTAL	60	60	60	60	60	60	60	60	60	60	600
		FREON	30	30	30	30	30	30	30	30	30	30	300
		OIL	30	30	30	30	30	30	30	30	30	30	300
PAINT CLEAN-UP	H20	TOTAL	50	50	50	50	50	50	50	50	50	50	500
		MEK	25	25	25	25	25	25	25	25	25	25	250
		MIN SPIRT	23	23	23	23	23	23	23	23	23	23	225
		SOLIDS	3	3	3	3	3	3	3	3	3	3	25
PC BOARD CLEANING	H21	TOTAL	60	60	60	60	60	60	60	60	60	60	600
		TRICH	24	24	24	24	24	24	24	24	24	24	240
		WATER	24	24	24	24	24	24	24	24	24	24	240
		IC3OH	3	3	3	3	3	3	3	3	3	3	30
		METHANOL	3	3	3	3	3	3	3	3	3	3	30
		ME CL	3	3	3	3	3	3	3	3	3	3	30
		FREON	3	3	3	3	3	3	3	3	3	3	30
PREPARATION OF TILE CLEANING KITS	H22	TOTAL	50	50	50	50	50	50	50	50	50	50	500
		IC3OH	10	10	10	10	10	10	10	10	10	10	100
		MEK	10	10	10	10	10	10	10	10	10	10	100
		111TCEA	10	10	10	10	10	10	10	10	10	10	100
		NAPHTHA	10	10	10	10	10	10	10	10	10	10	100
		ACETONE	10	10	10	10	10	10	10	10	10	10	100
DEGREASING GSE EQUIPMENT	H23	TOTAL	50	50	50	50	50	50	50	50	50	50	500
		WATER	30	30	30	30	30	30	30	30	30	30	300
		OIL	10	10	10	10	10	10	10	10	10	10	100
		UNKNOWN	10	10	10	10	10	10	10	10	10	10	100
SUBTOTAL STREAM GROUP "H"			2931	2931	2931	2931	2931	2931	2931	2931	2931	2931	29310

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
LOCKHEED (8310)	I1	TOTAL	990	990	990	990	990	990	990	990	990	990	9900
PARTS CLEANING		FREON	218	218	218	218	218	218	218	218	218	218	2178
SYSTEM FLUSH		IC3OH	218	218	218	218	218	218	218	218	218	218	2178
PARTS CLEANING		MEK	218	218	218	218	218	218	218	218	218	218	2178
PARTS CLEANING		ME CL	109	109	109	109	109	109	109	109	109	109	1089
PARTS CLEANING		111TCEA	59	59	59	59	59	59	59	59	59	59	594
SYSTEM FLUSH		METHANOL	109	109	109	109	109	109	109	109	109	109	1089
PAINT STRIPPING		UNKNOWN	59	59	59	59	59	59	59	59	59	59	594
FUELS LAB & DET 41 AFLC/MA	I2	TOTAL	438	438	438	438	438	438	438	438	438	438	4380
		FREON	118	118	118	118	118	118	118	118	118	118	1183
		IC3OH	53	53	53	53	53	53	53	53	53	53	526
		ME CL	13	13	13	13	13	13	13	13	13	13	131
		111TCEA	74	74	74	74	74	74	74	74	74	74	745
		TRICH	79	79	79	79	79	79	79	79	79	79	788
		MIBK	4	4	4	4	4	4	4	4	4	4	44
		ACETONE	61	61	61	61	61	61	61	61	61	61	613
		ETHANOL	4	4	4	4	4	4	4	4	4	4	44
		METHANOL	31	31	31	31	31	31	31	31	31	31	307
FEDERAL ELECTRIC CORP-ITT	I3	TOTAL	140	140	140	140	226	226	226	226	226	226	1916
		UNKNOWN	140	140	140	140	226	226	226	226	226	226	1916
PAINT THINNERS													
BOEING (6523)	I4	TOTAL	21	21	21	21	21	21	21	21	21	21	210
CLEANING		MEK	15	15	15	15	15	15	15	15	15	15	149
CLEANING		UNKNOWN	6	6	6	6	6	6	6	6	6	6	61

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
4392 TRNSS/L6TM	I5	TOTAL	2466	2466	2466	2466	2466	2466	2466	2466	2466	2466	24660
VEHICLE MAINTENANCE		UNKNOWN	74	74	74	74	74	74	74	74	74	74	740
DEGREASING		STODDARD	2392	2392	2392	2392	2392	2392	2392	2392	2392	2392	23920
394 ICBMTMS (6601)	I6	TOTAL	45	45	45	45	45	45	45	45	45	45	450
FACILITY MAINT.		IC3OH	1	1	1	1	1	1	1	1	1	1	9
FAC. MAINT. & REF.		MEK	12	12	12	12	12	12	12	12	12	12	122
MISSILE MAINT.		TRICH	1	1	1	1	1	1	1	1	1	1	9
DEGREASING		TOLUENE	3	3	3	3	3	3	3	3	3	3	32
DEGREASING		ACETONE	3	3	3	3	3	3	3	3	3	3	32
MAINT,REFURB,&PNEU		PD-620	25	25	25	25	25	25	25	25	25	25	248
1369 AVS/DOC(8314)	I7	TOTAL	120	120	120	120	120	120	120	120	120	120	1200
MOTION PICT. PROC.		ACETONE	120	120	120	120	120	120	120	120	120	120	1200
MARTIN MARIETTA	I8	TOTAL	76	76	76	76	76	76	76	76	76	76	760
SCAPE SUIT REPAIR (9325)		ALCOHOLS	1	1	1	1	1	1	1	1	1	1	8
DEGREASING (9325)		111TCEA	75	75	75	75	75	75	75	75	75	75	752
MECH. SECT./DEM	I9	TOTAL	60	60	60	60	60	60	60	60	60	60	600
PARTS CLEANING		PERC	60	60	60	60	60	60	60	60	60	60	600
STRUC. SECT./DEM	I10	TOTAL	60	60	60	60	60	60	60	60	60	60	600
PAINT REMOVAL		ME CL	60	60	60	60	60	60	60	60	60	60	600
394-COR.CON.(1930)	I11	TOTAL	65	65	65	65	65	65	65	65	65	65	650
METAL CLEANING		MEK	65	65	65	65	65	65	65	65	65	65	650
SUBTOTAL STREAM GROUP "I"			4481	4481	4481	4481	4567	4567	4567	4567	4567	4567	45326

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LOW LAUNCH RATE SCENARIO			1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
LAUNCHES PER YEAR---------)			1	2	2	3	4	5	6	7	8	9	47
STREAM DESCRIPTION	STRM ID	COMPONENT	VOLUME GENERATED IN GALLONS FOR THE TIME PERIOD										
SLC2W DELTA	J1	TOTAL	100	100	100	100	100	100	0	0	0	0	600
PROP.TRANS-2ND STG		FREON	100	100	100	100	100	100	0	0	0	0	600
SLC2W DELTA	J2	TOTAL	100	100	100	100	100	100	0	0	0	0	600
PROP.TRANS-2ND STG		IC3OH	100	100	100	100	100	100	0	0	0	0	600
SLC2W DELTA													
1ST STG.ENG. FLUSH	J3	TOTAL	45	45	45	45	45	45	0	0	0	0	270
		TRICH	45	45	45	45	45	45	0	0	0	0	270
SLC2E													
PAINTING, CLEANING,	J4	TOTAL	6	6	6	6	6	6	0	0	0	0	36
AND DEGREASING		UNKNOWN	6	6	6	6	6	6	0	0	0	0	36
SHOP--BLDG. 831	J5	TOTAL	200	200	200	200	200	200	0	0	0	0	1200
OIL/PAINT/THINNER		UNKNOWN	200	200	200	200	200	200	0	0	0	0	1200
SUBTOTAL STREAM GROUP "J"			451	451	451	451	451	451	0	0	0	0	2706
ATLAS & TITAN LNCH	K1	TOTAL	3680	5894	3680	5156	0	0	0	0	0	0	18410
AND CCF OPERATIONS		FREON	660	660	660	660	0	0	0	0	0	0	2640
		IC3OH	804	2010	804	1608	0	0	0	0	0	0	5226
		MEK	4	4	4	4	0	0	0	0	0	0	16
		111TCEA	330	330	330	330	0	0	0	0	0	0	1320
		TRICH	1210	1210	1210	1210	0	0	0	0	0	0	4840
		METHANOL	672	1680	672	1344	0	0	0	0	0	0	4368
SUBTOTAL STREAM GROUP "K"			3680	5894	3680	5156	0	0	0	0	0	0	18410
GRAND TOTALS			26646	39852	37638	46699	47815	53235	57718	62318	66673	70841	509437

TABLE 2-1.(Cont'd.)

DETAILED INVENTORY OF WASTE LIQUID SOLVENT GENERATION

LEGEND FOR COMPOUND NAME ABBREVIATIONS

ABBREV.	COMPOUND NAME
FREON	FREON-113 (1,1,2-1,2,2 TRICHLOROTRIFLUOROETHANE)
111TCEA	1,1,1 TRICHLOROETHANE
ETH ACET	ETHYL ACETATE
EGMBE	ETHYLENE GLYCOL MONOBUTYL ETHER
MIBK	METHYL ISOBUTYL KETONE
IC3OH	ISOPROPANOL
CELL ACET	CELLOSLOVE ACETATE
ME CL	METHYLENE CHLORIDE (DICHLOROMETHANE)
PERC	PERCHLOROETHYLENE
ME DIANIL	METHYLENE DIANILINE
MEK	METHYL ETHYL KETONE
CRES ACID	CRESYLIC ACID
TRICH	TRICHLOROETHYLENE
FORM ACID	FORMIC ACID
TURCO	TURCO 5873 NC (A PAINT STRIPPING COMPOUND)
CYHEXONE	CYCLOHEXANONE
PHOS ACID	PHOSPHORIC ACID
MIN SPIRT	MINERAL SPIRITS
RAM 225	MOLD RELEASE COMPOUND
ETH BENZ	ETHYL BENZENE
CARB TET	CARBON TETRACHLORIDE
STODDARD	STODDARD SOLVENT (A SPECIALTY NAPHTHA)
PD-620	DRY CLEANING SOLVENT

TABLE 2-2.

SUMMARY OF THE LIQUID SOLVENT WASTE GENERATION RATES

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL	
COMPONENT/LAUNCHES	1	2	2	3	4	5	6	7	8	9	47	VOL.%
	GENERATION RATES IN GALLONS FOR THE PERIOD											
FREON	14346	23323	23323	28896	32416	35933	38666	41266	43623	45793	327484	64.28
IC3OH	1929	3200	1994	2849	1286	1329	1269	1308	1346	1384	17896	3.51
MEK	753	1010	1010	1277	1539	1806	2073	2339	2606	2872	17285	3.39
ME CL	903	1513	1513	2124	2734	3345	3955	4565	5176	5786	31614	6.21
PERC	627	1147	1147	1667	2187	2707	3226	3746	4266	4786	25506	5.01
111TCEA	665	735	735	805	545	615	685	755	826	896	7263	1.43
TRICH	1364	1370	1370	1376	171	177	137	143	149	154	6411	1.26
MIBK	170	200	200	230	260	290	321	351	381	411	2813	0.55
TOLUENE	267	296	296	325	355	384	414	443	473	502	3755	0.74
ACETONE	204	224	224	243	263	282	302	321	341	360	2764	0.54
ETH ACET	1	1	1	2	3	4	4	5	6	6	33	0.01
XYLENE	17	19	19	22	24	26	28	30	33	35	253	0.05
EGMBE	18	22	22	25	28	32	35	38	41	45	305	0.06
ETHANOL	107	210	210	313	416	519	622	725	828	931	4885	0.96
ME DIANIL	11	22	22	33	44	55	66	77	88	99	517	0.10
CRES ACID	37	73	73	110	146	183	220	256	293	329	1720	0.34
FORM ACID	5	10	10	14	19	24	29	34	38	43	226	0.04
AMMONIA	0	0	0	0	0	0	0	0	0	0	0	0.00
N-BUTANOL	2	3	3	5	6	8	10	11	13	14	75	0.01
CYHEXONE	2	3	3	5	6	8	10	11	13	14	75	0.01
NAPHTHA	21	24	24	27	29	32	35	37	40	42	311	0.06
PHENOLICS	5	10	10	15	20	25	30	35	40	45	235	0.05
HEXANE	2	5	5	7	9	11	14	16	18	20	106	0.02

Note: Table continued on next page.

TABLE 2-2.(Cont'd.)

SUMMARY OF THE LIQUID SOLVENT WASTE GENERATION RATES

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL	
COMPONENT/LAUNCHES	1	2	2	3	4	5	6	7	8	9	47	VOL.%
	GENERATION RATES IN GALLONS FOR THE PERIOD											
PHOS ACID	30	30	30	30	30	30	30	30	30	30	300	0.06
MIN SPIRT	163	163	163	163	163	163	163	163	163	163	1625	0.32
RAM 225	0	0	0	0	0	0	0	0	0	0	1	0.00
FREON-11	20	20	20	20	20	20	20	20	20	20	198	0.04
ETH BENZ	19	19	19	19	19	19	19	19	19	19	192	0.04
CARB TET	20	20	20	20	20	20	20	20	20	20	200	0.04
METHANOL	815	1823	815	1487	143	143	143	143	143	143	5794	1.14
UNKNOWN	839	839	839	839	926	926	720	720	720	720	8083	1.59
DETERGENT	1	2	2	3	4	5	6	7	8	9	46	0.01
TURCO	3	5	5	8	10	13	15	18	20	23	118	0.02
AMINES	5	10	10	15	20	25	30	35	40	45	235	0.05
AROMATICS	10	20	20	30	40	50	60	70	80	90	470	0.09
KETONES	19	19	19	19	19	19	19	19	19	19	192	0.04
CHROMIUM	5	10	10	15	20	25	30	35	40	45	235	0.05
GLYCOL ET	5	10	10	15	20	25	30	35	40	45	235	0.05
ALCOHOLS	11	21	21	31	41	51	61	71	81	91	478	0.09
CELL ACET	5	10	10	15	20	25	30	35	40	45	235	0.05
WATER	187	257	257	327	397	468	538	608	678	748	4466	0.88
INK	0	0	0	0	0	0	0	0	0	0	3	0.00
SOLIDS	458	554	554	649	744	839	935	1030	1125	1220	8108	1.59
GREASE	2	2	2	2	2	2	2	2	3	3	22	0.00
DIRT	2	2	2	2	2	2	2	2	2	3	21	0.00
OIL	155	180	180	205	230	255	281	306	331	356	2478	0.49
STODDARD	2392	2392	2392	2392	2392	2392	2392	2392	2392	2392	23920	4.70
PD-620	25	25	25	25	25	25	25	25	25	25	248	0.05
GRAND TOTALS	26646	39852	37638	46699	47815	53235	57718	62318	66673	70841	509437	100.00

Note: These figures represent liquid waste solvent only, no solvents from vapor recovery are included.

3.0 CONCEPTUAL DESIGN OF THE PURIFICATION SYSTEM

None of the waste liquid solvents, or even the solvents from vapor recovery, are pure enough to be reused directly. The contaminants preventing reuse include other solvents, oils and grease, water, and a variety of solids and grit. Purification of these waste solvents may require one or all of the following:

* distillation,
* extraction,
* filtration, and
* dehydration.

The exact configuration of the purification equipment required depends on which solvent species are to be recovered, on the degree of contamination, and on the fresh solvent specifications for the solvents to be recovered.

This section begins with a review of the preliminary economics, which is the basis for the solvent purification selection. The waste solvent streams are then reviewed to decide which should be routed to the purification unit and which should be sent directly to offsite recovery/disposal. Once these basic decisions have been made, the average composition of the feed to the purification unit is presented. The remainder of the section is devoted to presenting the design options for the purification unit, the economics of those options, and the recommended conceptual design for the purification facility.

3.1 Selection Of Solvents To Be Purified

The choice of whether or not to purify and reuse a given solvent is based primarily on the volume of the waste solvent generated, the value of the solvent if purified, and the cost of purifying the solvent. Table 3-1 presents the results of a preliminary economic analysis of which solvents to purify. In this simplified analysis, the following conservative assumptions were made:

1. The solvent generation rate will be set at the maximum yearly rate that is generated during the expected life of the project, which is the 9 launch operation estimated for 1995.

2. The solvent value will be taken as the fresh solvent price with no deductions for the lost potential for offsite recovery.

3. The capital cost for the base unit to purify only Freon is estimated to be $1,000,000 and the

TABLE 3-1. PRELIMINARY ECONOMICS FOR RECOVERY OF VARIOUS SOLVENT SPECIES

Compound	Annual Generation Rate(1), GPY	Potential Gross Savings, $/yr.	Annualized Cost to Recover(2), $/yr.	Potential Net Savings, $/yr.
Freon	45,793	446,024	319,000	127,024
IC3OH	1,384	4,470	16,926	-12,456
MEK	2,872	9,879	16,926	-7,047
ME CL	5,786	24,590	16,926	7,664
PERC	4,786	12,204	16,926	-4,722
111TCEA	896	3,781	16,926	-13,145
TRICH	149	629	16,926	-16,297
MIBK	411	2,129	16,926	-14,797
TOLUENE	502	1,130	16,926	-15,796
ACETONE	360	522	16,926	-16,404
XYLENE	35	47	16,926	-16,879
ETHANOL	931	1,611	16,926	-15,315
N-BUTANOL	14	32	16,926	-16,894

Note: Table continued on the next page.

(1) This is the maximum annual generation rate projected for the 10 year life of the project, and corresponds to a 9 launch per year operation.

(2) The annualized cost to recover is a rough preliminary estimate of the operating and maintenace costs plus an allowance for capital recovery at 20%. The base case cost to recover Freon is estimated as an installed capital cost of $1,000,000 (for which the capital recovery allowance is $238,520 for a 10 year life) and the operating and maintenance costs are estimated to be $80,000 per year, giving a total annualized cost of about $319,000 per year. The facilities to recover any other solvent on an incremental basis are estimated to be (at a minimum) $50,000 capital, $5,000 O&M, and $16,926 per year total annualized cost.

TABLE 3-1. PRELIMINARY ECONOMICS FOR RECOVERY OF VARIOUS SOLVENT SPECIES (Cont'd.)

Compound	Annual Generation Rate(1), GPY	Potential Gross Savings, $/yr.	Annualized Cost to Recover(2), $/yr.	Potential Net Savings, $/yr.
CYHEXONE	14	67	16,926	-16,859
NAPHTHA	42	60	16,926	-16,867
HEXANE	20	21	16,926	-16,905
MINERAL SPIRITS	163	236	16,926	-16,690
CARBON TET.	20	71	16,926	-16,854
METHANOL	143	72	16,926	-16,855
METHYL DIANILINE	99	Not Available	NA	NA
WATER	748	0	16,926	-16,926
UNKNOWN	720	NA	NA	NA
INK	1	NA	NA	NA
SOLIDS	1,220	NA	NA	NA
GREASE	3	NA	NA	NA
DIRT	3	NA	NA	NA
OIL	356	254	16,926	-16,672

(1) This is the maximum annual generation rate projected for the 10 year life of the project, and corresponds to a 9 launch per year operation.

(2) The annualized cost to recover is a rough preliminary estimate of the operating and maintenace costs plus an allowance for capital recovery at 20%. The base case cost to recover Freon is estimated as an installed capital cost of $1,000,000 (for which the capital recovery allowance is $238,520 for a 10 year life) and the operating and maintenance costs are estimated to be $80,000 per year, giving a total annualized cost of about $319,000 per year. The facilities to recover any other solvent on an incremental basis are estimated to be (at a minimum) $50,000 capital, $5,000 O&M, and $16,926 per year total annualized cost.

operating and maintenance (O&M) costs are estimated to be $80,000/year. Using a capital recovery factor for 20% and a 10 year life, the cost of capital recovery is estimated to be $239,000/year. The total annualized cost is, therefore, $319,000/year.

4. The incremental capital cost to add equipment to purify any solvent in addition to Freon is estimated to be a minimum of $50,000. The incremental O&M costs are estimated to be $5000/year and the capital recovery cost is $11,926/year. This results in a minimum incremental annualized cost of $16,926/year.

This set of assumptions is designed to be very liberal in estimating the value of recovered solvents but very conservative in estimating the cost of purification, and should thus eliminate only those solvents which would be grossly uneconomical to purify and reuse. As demonstrated by the potential net savings column (solvent value - annualized cost of purification), only Freon and methylene chloride have any chance of being recovered economically.

3.2 Selection Of Streams For Purification

The waste solvent streams (presented in detail in Table 2-1) were carefully reviewed to determine which should be routed to the solvent purification unit. The one necessary positive attribute of a candidate solvent stream is that it contain a significant amount of one of the recoverable solvent species (Freon or methylene chloride). It is quite obvious that a stream that contains no recoverable solvents should be bypassed around the purification unit, since it would increase operating costs but would not add to the solvent savings. Since the potential savings for Freon recovery are far greater than for any other solvents, the base case considered will be for Freon recovery only. For that case, any stream with less than 5% Freon will be excluded, as well as any stream where the methylene chloride concentration is equal to or greater than the Freon concentration. The reason for excluding these streams is that a net loss of recoverable product would result. The Freon product specifications are so demanding that a significant amount of Freon must be sacrificed to both the light and heavy solvent waste streams. The more of this solvent waste that is present in the feed, the more Freon is lost. If the raw waste stream contains less than 5 percent Freon, then more Freon will be lost in the waste materials than is contributed by that stream. Streams where the methylene chloride concentration is equal to or greater than the Freon concentration are excluded

even when the Freon concentration is well above 5 percent, because the overhead product from the first distillation column is an azeotrope made up of about 50.5% Freon and 49.5% methylene chloride. The result of this azeotrope formation is that a volume of Freon slightly greater than that of the methylene chloride will be lost to the light solvent waste stream, negating any potential Freon recovery.

Some negative attributes of candidate streams were also considered in screening streams for routing to solvent purification. Some of the stream properties considered to have a negative impact included origination of the waste from some isolated point (such as Port Hueneme), the presence of acidic materials, the presence of undefined materials, a high water content, a high solids content, and the presence of a very complex mixture of compounds (especially when some of the compounds were unique to that stream). Table 3-2 presents a summary of the results of that candidate stream screening operation, including the specific reason(s) for rejecting any stream. Table 3-3 presents the average composition of the resulting feed to the purification unit. It should be noted that this feed represents only the waste liquid solvents and not the solvent from any vapor recovery operation.

3.3 Purification Facility Design Options

The military specifications for Freon-113 are presented in Table 3-4. It is readily apparent from comparing the composite solvent feed characteristics to the military specifications that the Freon must be concentrated from about 91% to 99.9+% and that it must also be dried, de-acidified, and filtered. Although it is theoretically possible to concentrate the Freon using many different processes, the only process with any commercially demonstrated experience is fractional distillation preceded by a water-wash. The acid number specification can be met by a combination of excluding acidic materials from the feed, as much as possible, and removing most of any remaining acidic material by the water wash. The dehydration step is typically carried out using a hydrophilic adsorbent such as a molecular sieve or silica gel. The particulate matter specification can be met by filtration.

There are several optional configurations for the purification system that will be considered in the conceptual design phase. The base case will be a distillation-based separation of Freon only from the waste solvent mixture, with auxiliary processes as necessary to achieve Type I specifications. The second case to be considered is a design based on purification of both Freon and methylene chloride, by the addition of an extraction/stripping system to the light solvent waste produced in the base case. Another option to be considered in the conceptual design is the use of batch vs.

TABLE 3-2. WASTE SOLVENT STREAM SCREENING

Stream ID	Streams Selected for Purification	Streams Rejected	Reasons for Rejection
A1		A1	1
B1		B1	1
B2		B2	1
B3	B3		
C1		C1	1
C2		C2	1
C3		C3	1
C4		C4	1
C5		C5	1
C6		C6	1,3,6
C7		C7	1
D1-D5		D1-D5	2
E1		E1	1
F1	F1(a)		
F2	F2(a)		

Note: Table continued on following pages.

REASONS FOR REJECTION:

1--This stream contains no recoverable solvent.
2--This stream originates at an isolated point and it would be impractical to recover it, such as streams D1-D5 which come from Port Hueneme.
3--This stream contains acidic materials which could make it difficult to meet the acid number specification or require further treatment.
4--This stream contains significant quantities of undefined materials which could potentially have an adverse effect on the separations.
5--This stream has a high water content.
6--This stream has a high solids content.
7--This stream will not be applicable to the operations at VAFB.

Explanatory Notes:

(a) The streams from Group F (SCAPE suit cleaning) that are routed to purification represent only the bottoms rejected from the self-contained Freon recovery cleaning booth that it is likely to be used at VAFB.

TABLE 3-2. WASTE SOLVENT STREAM SCREENING (Cont'd.)

Stream ID	Streams Selected for Purification	Streams Rejected	Reasons for Rejection
G1	G1		
G2		G2	1
G3	G3		
G4	G4		
G5		G5	1
G6		G6	1,3,4
G7		G7	1
G8		G8	1
G9	G9		
G10		G10	7
G11	G11		
G12		G12	1,3
H1		H1	1
H2		H2	1
H3		H3	1
H4		H4	1,4,6
H5		H5	1,4,6
H6		H6	1
H7		H7	1,4
H8		H8	1,5
H9		H9	1,4
H10	H10		
H11	H11		
H12	H12		

Note: Table continued on following pages.

REASONS FOR REJECTION:

1--This stream contains no recoverable solvent.
2--This stream originates at an isolated point and it would be impractical to recover it, such as streams D1-D5 which come from Port Hueneme.
3--This stream contains acidic materials which could make it difficult to meet the acid number specification or require further treatment.
4--This stream contains significant quantities of undefined materials which could potentially have an adverse effect on the separations.
5--This stream has a high water content.
6--This stream has a high solids content.
7--This stream will not be applicable to the operations at VAFB.

TABLE 3-2. WASTE SOLVENT STREAM SCREENING (Cont'd.)

Stream ID	Streams Selected for Purification	Streams Rejected	Reasons for Rejection
H13		H13	1
H14	H14		
H15		H15	1
H16		H16	1
H17		H17	1,4
H18	H18		
H19	H19		
H20		H20	1,6
H21		H21	1
H22		H22	1
H23		H23	1
I1	I1		
I2	I2		
I3		I3	1,4
I4		I4	1,4
I5		I5	1,4
I6		I6	1
I7		I7	1
I8		I8	1
I9		I9	1
I10		I10	1
I11		I11	1
J1	J1		
J2		J2	1
J3		J3	1
J4		J4	1,4
J5		J5	1,4
K1	K1		

REASONS FOR REJECTION:

1--This stream contains no recoverable solvent.
2--This stream originates at an isolated point and it would be impractical to recover it, such as streams D1-D5 which come from Port Hueneme.
3--This stream contains acidic materials which could make it difficult to meet the acid number specification or require further treatment.
4--This stream contains significant quantities of undefined materials which could potentially have an adverse effect on the separations.
5--This stream has a high water content.
6--This stream has a high solids content.
7--This stream will not be applicable to the operations at VAFB.

TABLE 3-3.

SUMMARY OF THE LIQUID WASTE FEED TO THE PURIFICATION UNIT

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL	
COMPONENT/LAUNCHES	1	2	2	3	4	5	6	7	8	9	47	VOL.%
	GENERATION RATES IN GALLONS FOR THE PERIOD											
FREON	14511	23726	23726	29539	33298	36954	40026	42866	45461	47870	337977	91.68
IC3OH	1135	2385	1179	2012	429	450	469	487	504	520	9568	2.60
MEK	222	222	222	222	218	218	218	218	218	218	2195	0.60
ME CL	122	122	122	122	122	122	122	122	122	122	1220	0.33
111TCEA	464	464	464	464	134	134	134	134	134	134	2659	0.72
TRICH	1289	1289	1289	1289	79	79	79	79	79	79	5628	1.53
MIBK	4	4	4	4	4	4	4	4	4	4	44	0.01
TOLUENE	15	30	30	45	60	75	90	105	120	135	704	0.19
ACETONE	61	61	61	61	61	61	61	61	61	61	613	0.17
ETHANOL	4	4	4	4	4	4	4	4	4	4	44	0.01
NAPHTHA	3	5	5	8	11	13	16	18	21	24	124	0.03
METHANOL	812	1820	812	1484	140	140	140	140	140	140	5764	1.56
UNKNOWN	60	60	60	60	60	60	61	61	61	61	604	0.16
WATER	18	18	18	18	18	18	18	18	18	18	181	0.05
INK	0	0	0	0	0	0	0	0	0	0	3	0.00
SOLIDS	2	2	2	2	2	2	2	2	2	2	20	0.01
GREASE	1	1	1	1	1	1	1	1	1	1	11	0.00
DIRT	0	0	0	0	0	0	0	0	0	0	1	0.00
OIL	128	128	128	128	128	128	128	128	128	128	1280	0.35
GRAND TOTALS	18851	30342	28128	35464	34769	38464	41573	44448	47078	49521	368640	100.00

NOTE: THESE FIGURES INCLUDE ONLY WASTE LIQUID SOLVENTS (NO SOLVENTS FROM VAPOR RECOVERY)

TABLE 3-4. MILITARY SPECIFICATIONS FOR FREON-113

Property	Requirement		
	Type I	Type II	Type IIA
Boiling point (degrees C)	47.6 ± 0.2	47.6 ± 0.2	47.6 ± 0.2
Chemical purity (percent)	99.9	99.8	99.8
Maximum moisture content (ppmw)	10	10	50
Maximum cloride ion (ppmw)	0.1	0.1	0.1
Max. acid no. (mgKOH/g sample)	0.003	0.003	0.003
Maximum residue (ppmw)	1	2	25
Max. particulates (No./100 ml):			
25 to 100 microns---	100	---	---
100 microns-------	10	---	---
Balance of product	--------Other Halogenated Solvents--------		

Source: Military specification MILC-81302C
Note: The abbreviation ppmw denotes parts per million by weight.

continuous distillation technology.

Batch distillation is an intermittent process in which a fixed quantity of waste solvent would be charged to a still and progressively heated to boil off the lighter compounds. This type of distillation is used very effectively where a low-boiling solvent is contaminated with much higher-boiling greases, oils, etc., but it is of limited applicability to a situation where the solvent to be recovered is contaminated with both lighter and heavier materials. A batch distillation unit could be designed with a slow temperature escalation, high reflux ratios, many trays, and a sophisticated control system, such that the light solvent waste would be boiled off first, after which the condensate could be diverted to the product tank. The operation of such a unit to consistently produce on-specification Type I Freon would require the close attention of a skilled operator, and even then a significant number of off-specification batches would be expected. This can be contrasted with a continuous fractionation unit which operates with as near to steady-state conditions as possible. The lighter solvent wastes would be removed in one column and the Freon boiled out of the heavy contaminants in a second column. This type of continuous fractionation unit may require some adjustment at the start of a run to get the product on-specification, but once that is achieved, the control system will maintain those conditions with a high degree of reliability. Although a continuous distillation unit may cost 50 to 100% more than a batch unit, the use of continuous distillation is recommended for the VAFB solvent purification facility because of the demonstrated ability to produce Type I Freon on-specification and the lower requirements for operator attention/sophistication.

3.3.1 Base Case Conceptual Design

The base case configuration for a purification facility to recover only Freon is represented schematically in Figure 3-1. This configuration is almost identical to the unit successfully recovering Freon at the Newark Air Force Station (NAFS). Bulk and drummed waste solvents are collected in one of two feed mix tanks until a sufficient volume has accumulated to make a two-week run. The resulting feedstock will be sampled and the results used to adjust the operating set-points for the purification unit. The feed mix tanks will provide enough mixing and residence time to dampen out any fluctuations in the feed composition.

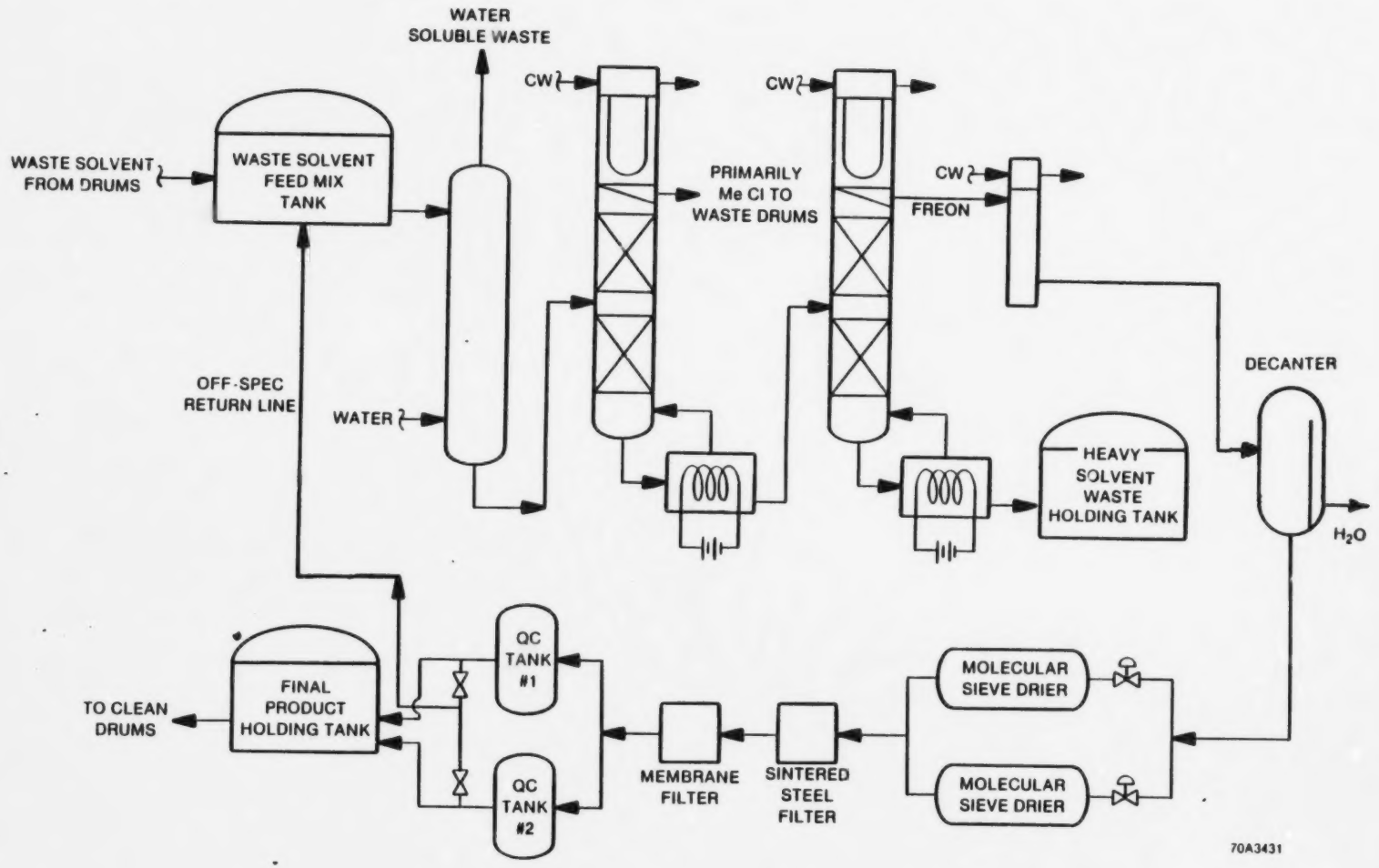

FIGURE 3-1. SCHEMATIC DIAGRAM OF THE BASE CASE PURIFICATION FACILITY

The unit feed will be pumped to the water-wash column for a preliminary separation of water soluble contaminants, primarily the alcohols and ketones. The water-wash column uses a pulsed-flow technique to establish a counter-current contact between the waste solvent and the water. Since Freon is more dense than water, the solvent waste stream is added to the top of the water-wash column and removed from the bottom. The water-wash column bottoms flow to a small collection tank and then to the feed tray of the light ends removal column. It should also be noted that a wastewater stream will be generated from the water wash column. While the purification unit is in operation, the wastewater stream will be generated at a rate of about 2 gallons per minute, but the maximum annual generation rate will be only about 240,000 gallons (based on an estimated 2000 operating hours per year). The primary organic contaminants and their expected concentrations in the wastewater are:

0.17 wt.%	isopropanol
0.11 wt.%	MEK
0.60 wt.%	methylene chloride
0.03 wt.%	trichloroethylene
0.02 wt.%	MIBK
0.05 wt.%	acetone
0.15 wt.%	ethanol
0.01 wt.%	cyclohexanone.

It is expected that this wastewater would be stripped with a stream of dry nitrogen to remove most of the marginally soluble halogenated organics. The nitrogen plus stripped organics stream could then be routed to the carbon adsorption unit (see Section 4) to avoid any additional atmospheric emissions.

The light ends column is designed to remove anything boiling lower than Freon, in this case primarily methylene chloride. Some Freon must also be lost in the overhead of this column in order to insure that essentially all light contaminants are reduced to the point where the Type I purity specifications can be met. The amount of Freon lost overhead increases with increasing methylene chloride concentration, since methylene chloride and Freon form an azeotrope (or constant boiling mixture) at a composition of 49.5% to 50.5%, respectively.

The bottoms from the light ends column are fed to the Freon product column, where the Freon is taken overhead while the higher boiling solvents, oils, and greases remain in the bottoms product (heavy solvent waste). The Freon leaving the overhead of the product column would meet the Type I purity specifications, but it still requires further processing to meet the water and particulate matter specifications. The water content

can be effectively reduced by the use of molecular sieve adsorbents. The molecular sieve beds are contained in two vessels which are operated in cyclic fashion, with one adsorbing while the other is regenerating. The particulate matter specification can be met by two stage filtration. The first stage filter uses a sintered steel material and is set up to allow back-flushing. The final filter uses a membrane sized to pass particles of two microns and less.

The finished Freon is held in one of two quality control tanks until it has been confirmed that it meets Type I specifications. If a given run should produce a quantity of off-specification Freon, that solvent would be recycled to the solvent mix tank and rerun. On specification product would be transferred to the final product tanks, from which it would be disbursed as needed.

Table 3-5 presents an estimate of the installed capital cost of such a facility, while the annual operating and maintenance costs are presented in Table 3-6. The purchased equipment cost is based primarily on a quote from Artisan Industries (the firm that designed and constructed the Newark AFS unit) of $750,000 for the current cost of a solvent purification unit like the one at Newark Air Force Station. That is the complete cost for a skid-mounted unit with vessels, piping, and instrumentation in place. The installation costs for such a package unit are minimal, and have been estimated as a total of $45,000 to cover on-site piping and electrical connections and operator training. The total installed cost of the solvent purification facility is estimated to be $795,000.

Table 3-7 presents a calculation of the solvent credits attributable to the purification unit. The primary credit for recovering spent solvent is the savings achieved by reducing purchases of fresh solvent. After a thorough search, it was discovered that the Air Force has no current contract price for the purchase of Freon-113, apparently because all of the precision cleaning work done with this solvent is performed by contractors. An Air Force price of $9.74 per gallon for Freon-113 was supplied by Aerospace Corporation based on information received from the San Antonio Air Logistics Center at Kelly AFB has been used as the basis for the calculations in this report. It should be noted that this price is significantly lower than the current (December 1983) spot market quotes of more than $11.00 per gallon as reported in the "Chemical Marketing Reporter".

TABLE 3-5. INSTALLED CAPITAL COST ESTIMATES--PURIFICATION BASE CASE

COST ITEM	ESTIMATED COST ($1000)
Purchase price for a skid-mounted, prefabricated solvent purification unit, as per Figure 3-1, including all vessels, piping, and instrumentation.	750 *
Installation-related costs:	
Auxiliary piping and electrical system connections	25
Start-up and operator training	20
Total Installation Costs	45
TOTAL INSTALLED COST=	795

* Purchase price based on an estimate from Artisan Industries for a new unit of similar design to Newark AFS. Quoted during a phone conversation between Mr. Ed Cherenson of Artisan and Graham Harris of Radian on January 10,1984.

TABLE 3-6. SUMMARY OF OPERATING AND MAINTENANCE COSTS

PURIFICATION FACILITY BASE CASE--FREON RECOVERY ONLY

795000=INSTALLED CAPITAL COST IN 1983 DOLLARS *

YEAR	SOLVENT LOADING GAL/YEAR	LABOR & MAINT. MATERIAL $/YR	TAXES+ INSUR.+ G&A $/YR	UTILITY COSTS ELECTRIC $/YR	STEAM $/YR	COOLING WATER $/YR	TOTAL OPERATING AND MAINTENANCE COSTS $/YR
1986	18851	18158	22267	4404	0	95	44924
1987	30342	29226	29627	7089	0	153	66096
1988	28128	27094	28310	6572	0	142	62118
1989	35464	34160	32534	8286	0	179	75159
1990	34769	33490	32150	8123	0	176	73939
1991	38464	37049	34158	8987	0	194	80388
1992	41573	40044	35789	9713	0	210	85756
1993	44448	42814	37254	10385	0	224	90677
1994	47078	45347	38562	10999	0	238	95145
1995	49521	47700	39750	11570	0	250	99270
TOTALS	368640	355082	330401	86128	0	1861	773471

* Capital cost based on a quote from Artisan Industries for a system like the one at Newark AFS, with installation related costs estimated by factors from: Drew,J.F., How to Estimate the Cost of Pilot Plant Equipment, Chemical Engineering magazine, February 9, 1970.

TABLE 3-7. SUMMARY OF THE RECOVERY CREDITS

BASE CASE--FREON PURIFICATION ONLY

FREON-113
FRESH SOLVENT VALUE= 9.74$/GAL. *
OFFSITE RECOVERY DEBIT= 1.90$/GAL. **

YEAR	FEED GAL./YR.	RECOVERED SOLVENT GAL./YR.	FRESH SOLVENT VALUE $/YEAR	OFFSITE RECOVERY DEBIT $/YEAR	NET RECOVERY CREDIT $/YEAR
1986	14511	13495	131439	25640	105799
1987	23726	22066	214918	41925	172994
1988	23726	22066	214918	41925	172994
1989	29539	27471	267569	52195	215374
1990	33298	30967	301620	58838	242783
1991	36954	34367	334733	65297	269436
1992	40026	37224	362566	70726	291840
1993	42866	39865	388286	75744	312542
1994	45461	42279	411796	80330	331466
1995	47870	44519	433618	84587	349032
TOTAL	337977	314319	3061465	597206	2464259

* No Air Force price was currently available for the Freon-113; the $9.74 is a current Air Force contractor's price for Freon-113.

** The offsite recovery credit is the average of the credits quoted by offsite recycling firms in the report: Off-Base Hazardous Waste Disposal/ Treatment Study for the Space Shuttle Project Vandenberg AFB, prepared by EMCON Associates, September, 1982.

The calculation of the true solvent recovery credit, however, must also take into account the disposal cost or salvage value that the spent solvent would have if it were not recovered on-site. The report "Off-Base Hazardous Waste Disposal/Treatment Study for the Space Shuttle Project Vandenberg AFB", prepared by EMCON Associates for the HQ Space Division, presented a thorough review of off-site disposal possibilities. Spent solvent wastes containing more than 50% to 75% Freon-113 were found to have a salvage value of from $1.00 to $3.50 per gallon of waste based on quotes from all solvent recyclers within several hundred miles of Vandenberg. The average of the salvage value quotes was $1.90 per gallon. Since this salvage value would be lost if the Freon is recovered on-site, it is treated as a debit in calculating the net credit for solvent recovery. The net result should be a conservatively high offsite recovery debit which can be used to adjust the credit for onsite recovery. The net onsite Freon recovery credit is $7.84 ($9.74 - $1.90).

Table 3-8 presents a net present value (NPV) calculation for the purification unit based on a projected 10 year life and using a discount factor of 11.75%, which is the current interest rate on long term Treasury Bonds. The net present value of the purification unit investment is about $63,488 at the T-Bond discount rate. This means that if the government raised the money to finance the purification unit by selling T-Bonds, that the net savings (after repaying the principal, all operating costs, and the interest on the debt) would be $63,488, over the projected 10 year economic life of the project.

The economic analysis presented in Table 3-8 was done on an inflation excluded basis. This is a common technique that is based on the assumption that any increases in the recovered product value will be offset by higher labor and materials costs. In this particular case, however, the impact on the solvent savings is substantially greater than the increase in labor and materials, resulting in a more attractive net present value for the project. Table 3-9 presents a calculation of the net present value for the base case purification unit assuming a 5% general inflation rate, while Figure 3-2 graphically presents the NPV for the system as a function of the general inflation rate. There are as many estimates as to the future inflation rate as there are economic experts, so no certain value will be assumed here. It is worth noting, however, that even rather low rates of inflation (such as have occurred in recent years) will result in a substantial improvement of the net present value of the solvent purification facility.

TABLE 3-8. NET PRESENT VALUE CALCULATIONS

INFLATION EXCLUDED BASIS
PURIFICATION UNIT BASE CASE--FREON RECOVERY ONLY

DISCOUNT FACTOR=11.75 % * NET FREON VALUE=7.84 $/GALLON **

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	795000	-795000
1986	105799	44924	60875	0.89	54474	0	-740526
1987	172994	66096	106898	0.80	85600	0	-654926
1988	172994	62118	110876	0.72	79450	0	-575475
1989	215374	75159	140216	0.64	89910	0	-485566
1990	242783	73939	168843	0.57	96883	0	-388683
1991	269436	80388	189048	0.51	97071	0	-291612
1992	291840	85756	206083	0.46	94691	0	-196921
1993	312542	90677	221865	0.41	91224	0	-105697
1994	331466	95145	236321	0.37	86951	0	-18746
1995	349032	99270	249762	0.33	82234	0	63488
TOTALS	2464259	773471	1690788	NA	858488	795000	63488

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

** The recovery credit of $7.84 results from a fresh Freon price of $9.74, corrected for the loss of the offsite recovery credit of $1.90.

Note: The exact return on investment for this case is 13.28%, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

TABLE 3-9. NET PRESENT VALUE CALCULATIONS

INFLATION INCLUDED BASIS
PURIFICATION UNIT BASE CASE--FREON RECOVERY ONLY

DISCOUNT FACTOR=11.75% *
GENERAL INFLATION RATE=5.00%

NET FREON VALUE=7.84 $/GALLON **

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	795000	-795000
1986	111089	47170	63918	0.89	57198	0	-737802
1987	190726	72870	117855	0.80	94375	0	-643428
1988	200262	71909	128353	0.72	91974	0	-551454
1989	261789	91356	170433	0.64	109286	0	-442168
1990	309859	94367	215492	0.57	123650	0	-318519
1991	361070	107727	253343	0.51	130084	0	-188435
1992	410648	120668	289980	0.46	133240	0	-55195
1993	461767	133971	327796	0.41	134779	0	79585
1994	514213	147602	366611	0.37	134889	0	214474
1995	568536	161700	406835	0.33	133950	0	348424
TOTALS	3389958	1049341	2340617	NA	1143424	795000	348424

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

** The recovery credit of $7.84 results from a fresh Freon price of $9.74, corrected for the loss of the offsite recovery credit of $1.90.

NOTE: The exact return on investment for this case is 18.95%, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

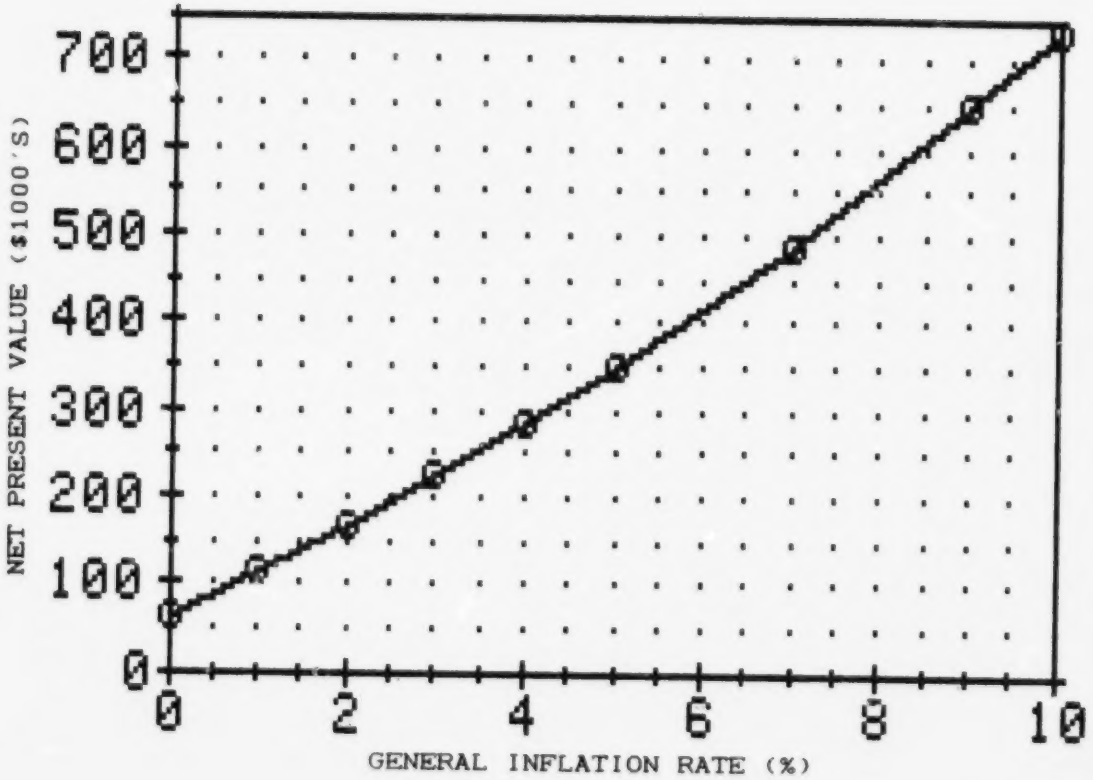

FIGURE 3-2. EFFECT OF GENERAL INFLATION ON NET PRESENT VALUE-BASE CASE FREON PURIFICATION FACILITY

3.3.2 Optional Methylene Chloride and Freon Recovery Case

The primary option to the base case purification scenario is the combined recovery and purification of both Freon and methylene chloride. If methylene chloride is to be recovered, the selection of streams to route to the purification unit changes significantly. Streams C2, C6, C7, E1, G6, G8, H1, H15, H16, and I10 were rejected in the base case for Freon recovery alone, but should be added to the inventory for combined methylene chloride and Freon recovery. Table 3-10 presents the average composition of the feed to purification for the optional methylene chloride recovery case.

Recovery of methylene chloride requires some extra processing of the overhead stream from the light ends removal column. The overhead from that column is an azeotrope of about 50.5% Freon and 49.5% methylene chloride, which cannot be further separated by conventional distillation. Figure 3-3 shows a schematic diagram of the processing needed to purify methylene chloride in addition to Freon. The heart of that system is an extraction/stripping process, in which the methylene chloride is removed from the Freon by water washing and then stripped from the water by nitrogen and condensed. The recovered methylene chloride would also require filtration and dehydration before meeting final product specifications.

Table 3-11 presents estimates of the incremental capital costs for the addition of equipment to purify methylene chloride, while Table 3-12 presents estimates of the operating costs. Table 3-13 presents a calculation of the recovery credits for methylene chloride and for the incremental Freon recovery over the base case. Table 3-14 presents the NPV calculations for that option on an inflation excluded basis. The net annual cash flow is very small, even before discounting. This means that the option of purifying methylene chloride can barely cover the additional operating costs, much less repay the capital investment and provide a return on that investment. Based on these results, it is clearly not economically attractive to purify methylene chloride at the rates and concentrations projected for VAFB.

TABLE 3-10. SUMMARY OF THE LIQUID WASTE FEED TO THE PURIFICATION UNIT
OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

COMPONENT	GENERATION RATES IN GALLONS FOR THE PERIOD											
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL VOLUME	%
FREON	14596	23840	23840	29680	33468	37151	40252	43119	45743	48180	339868	77.98
ME CL	851	1412	1412	1973	2534	3095	3656	4217	4778	5339	29262	6.71
IC3OH	1150	2415	1209	2057	489	525	559	592	624	655	10273	2.36
MEK	245	268	268	291	310	333	356	379	402	425	3276	0.75
PERC	548	1048	1048	1548	2048	2548	3048	3548	4048	4548	23975	5.50
111TCEA	523	526	526	529	202	205	208	211	214	217	3360	0.77
TRICH	1294	1299	1299	1304	99	104	109	114	119	124	5863	1.35
MIBK	27	50	50	73	96	119	142	165	188	211	1125	0.26
TOLUENE	21	41	41	62	82	103	123	144	165	185	967	0.22
ACETONE	78	95	95	111	128	144	161	178	194	211	1393	0.32
XYLENE	2	3	3	5	6	8	10	11	13	14	75	0.02
ETHANOL	92	180	180	268	356	444	532	620	708	796	4180	0.96
ME DIANIL	11	22	22	33	44	55	66	77	88	99	517	0.12
CRES ACID	16	31	31	47	62	78	94	109	125	140	733	0.17
N-BUTANOL	2	3	3	5	6	8	10	11	13	14	75	0.02
CYHEXONE	2	3	3	5	6	8	10	11	13	14	75	0.02
NAPHTHA	3	5	5	8	11	13	16	18	21	24	124	0.03
PHENOLICS	5	10	10	15	20	25	30	35	40	45	235	0.05
MIN SPIRT	140	140	140	140	140	140	140	140	140	140	1400	0.32
CARB TET	20	20	20	20	20	20	20	20	20	20	200	0.05
METHANOL	812	1820	812	1484	140	140	140	140	140	140	5764	1.32
UNKNOWN	60	60	60	60	60	60	61	61	61	61	604	0.14
DETERGENT	1	2	2	3	4	5	6	7	8	9	46	0.01
WATER	21	24	24	27	30	33	36	39	42	45	322	0.07
INK	0	0	0	0	0	0	0	0	0	0	3	0.00
SOLIDS	13	25	25	36	48	59	71	82	93	105	557	0.13
GREASE	1	1	1	1	1	1	1	1	1	1	11	0.00
DIRT	2	2	2	2	2	2	2	2	2	2	16	0.00
OIL	133	138	138	143	148	153	158	163	168	173	1515	0.35
GRAND TOTALS	20666	33482	31268	39929	40559	45579	50013	54213	58168	61936	435815	100.00

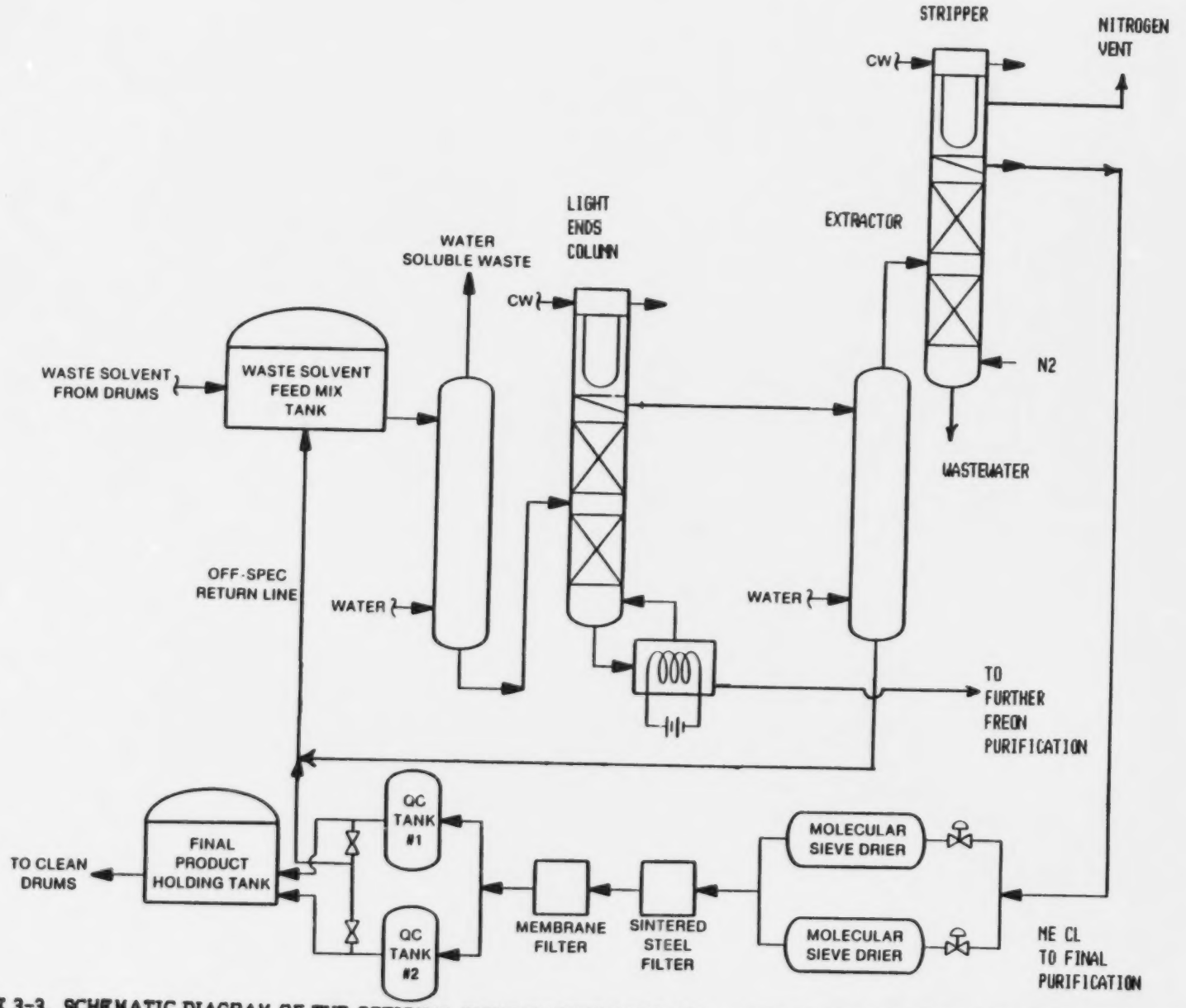

FIGURE 3-3. SCHEMATIC DIAGRAM OF THE OPTIONAL PURIFICATION FACILITY – METHYLENE CHLORIDE AND FREON RECOVERY

TABLE 3-11. INCREMENTAL CAPITAL COST ESTIMATES

OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

COST ITEM	ESTIMATED COST($1000) *
Methylene chloride extraction column with packed internals	19.0
Methylene chloride stripping column with packed internals	12.0
Product/reflux condenser	2.7
Product/reflux pump	4.2
Product filters	3.7
Product dehydrators	21.5
Product tank	4.2
TOTAL PURCHASED EQUIPMENT COSTS	64.6

* Capital and installation cost estimates are calculated from cost correlations given in "How to Estimate the Cost of Pilot Plant Equipment", by J.W.Drew and A.F.Ginder (Chem-Pro Equip.) in Chemical Engineering magazine, February 9, 1970. Costs were scaled to mid-1983 dollars using the Marshall & Stevens Cost Index.

Note: Table continued on the next page.

TABLE 3-11. INCREMENTAL CAPITAL COST ESTIMATES (Cont'd.)

OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

COST ITEM	ESTIMATED COST($1000) *
Installation related costs:	
Erection and foundations	7.1
Piping	51.7
Electrical	9.7
Instrumentation and control	16.8
Insulation and painting	16.1
Engineering, start-up, and training	29.1
TOTAL INSTALLATION COSTS	130.5
TOTAL INSTALLED COST	195.1

* Capital and installation cost estimates are calculated from cost correlations given in "How to Estimate the Cost of Pilot Plant Equipment", by J.W.Drew and A.F.Ginder (Chem-Pro Equip.) in Chemical Engineering magazine, February 9, 1970. Costs were scaled to mid-1983 dollars using the Marshall & Stevens Cost Index.

TABLE 3-12. INCREMENTAL OPERATING COST ESTIMATES

OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

COST ITEM	ESTIMATED COST($1000/YR)*
ANNUAL COSTS OF OPERATING AND MAINTENANCE:	
Labor plus maintenance materials	11.7
Taxes, insurance, and G&A	9.8
Utilities--	
Electricity	2.1
Cooling water	0.6
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS	24.2

* Operating and maintenance costs estimated by standard factored techniques as documented in: Guthrie, K.M., XProcess Plant Estimating,Y XEvaluation, and ControlY, Craftsman Book Company of America, Solana Beach, California, 1974.

TABLE 3-13. SUMMARY OF THE RECOVERY CREDITS
OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

	FREON-113 FRESH SOLVENT VALUE= 9.74$/GAL. OFFSITE RECOVERY DEBIT= 1.90$/GAL.							METHYLENE CHLORIDE FRESH SOLVENT VALUE= 4.25$/GAL. OFFSITE RECOVERY DEBIT= 0.90$/GAL.					
			INCREMENTAL				INCREMENTAL						
		RECOVERED	BASE CASE RECOV.	FREON RECOV.	FRESH SOLVENT	OFFSITE RECOVERY	NET RECOVERY		RECOVERED	FRESH SOLVENT	OFFSITE RECOVERY	NET RECOVERY	TOTAL RECOVERY
YEAR	FEED GAL./YR.	SOLVENT GAL./YR.	SOLV. GAL./YR.	SOLV. GAL./YR.	VALUE $/YEAR	DEBIT $/YEAR	CREDIT $/YEAR	FEED GAL./YR.	SOLVENT GAL./YR.	VALUE $/YEAR	DEBIT $/YEAR	CREDIT $/YEAR	CREDIT $/YEAR
1986	14596	13866	13495	371	3616	705	2910	851	765	3253	689	2564	5475
1987	23840	22648	22066	582	5668	1106	4562	1412	1270	5399	1143	4256	8818
1988	23840	22648	22066	582	5668	1106	4562	1412	1270	5399	1143	4256	8818
1989	29680	28196	27471	725	7065	1378	5687	1973	1775	7545	1598	5947	11634
1990	33468	31794	30967	827	8056	1572	6485	2534	2280	9691	2052	7639	14123
1991	37151	35294	34367	927	9025	1760	7264	3095	2785	11837	2507	9330	16594
1992	40252	38239	37224	1015	9888	1929	7959	3656	3290	13982	2961	11021	18981
1993	43119	40963	39865	1098	10696	2087	8610	4217	3795	16128	3415	12713	21323
1994	45743	43455	42279	1176	11459	2235	9224	4778	4300	18274	3870	14404	23628
1995	48180	45771	44519	1252	12192	2378	9814	5339	4805	20420	4324	16096	25910
TOTAL	339868	322875	314319	8556	83333	16256	67077	29262	26336	111929	23703	88226	155303

* The offsite recovery debits ($1.90 for Freon and $0.90 for methylene chloride) are averages of the credits quoted by offsite recycling firms in the report: Off-Base Hazardous Waste Disposal/Treatment Study for the Space Shuttle Project Vandenberg AFB, prepared by EMCON Associates, September 1982.

TABLE 3-14. NET PRESENT VALUE CALCULATIONS

INFLATION EXCLUDED BASIS
OPTIONAL METHYLENE CHLORIDE AND FREON RECOVERY CASE

DISCOUNT FACTOR=11.75 % * NET METHYLENE CLORIDE VALUE=3.35 $/GALLON **

YEAR (A)	TOTAL VALUE OF INCREMENTAL SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	195100	-195100
1986	5475	5113	361	0.89	323	0	-194777
1987	8818	8236	582	0.80	466	0	-194311
1988	8818	8236	582	0.72	417	0	-193894
1989	11634	10867	768	0.64	492	0	-193402
1990	14123	13192	932	0.57	535	0	-192867
1991	16594	15499	1095	0.51	562	0	-192305
1992	18981	17728	1252	0.46	575	0	-191729
1993	21323	19916	1407	0.41	578	0	-191151
1994	23628	22069	1559	0.37	574	0	-190577
1995	25910	24200	1710	0.33	563	0	-190014
TOTALS	155303	145056	10247	NA	5086	195100	-190014

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

** The recovery credit of $3.35 results from a fresh methylene chloride price of $4.25 corrected for the loss of the offsite recovery credit of $0.90.

NOTE: All of the cost figures in this table represent the incremental cost or savings over the base case for Freon recovery alone. The savings figures include both methylene chloride and the incremental Freon recovered.

4.0 CONCEPTUAL DESIGN OF VAPOR RECOVERY SYSTEM

The conceptual design of vapor recovery facilities for VAFB was started with a preliminary screening to determine which sites could possibly justifiy the investment required for vapor recovery. For those sites which survived the screening operation, a review of potentially applicable vapor recovery technologies was conducted. Finally, the conceptual design, cost estimates, and life-cycle economics were developed for the selected technology.

4.1 Preliminary Screening of Vapor Recovery Sites

The application of vapor recovery was evaluated for all of the solvent use areas, and Table 4-1 presents the preliminary economics for the application of a vapor recovery unit to these sources. The capital and operating costs given in that table represent rough estimates of the minimum costs of vapor recovery. The solvent credits represent the maximum achievable savings (assuming that 100% of the Freon vapors lost in each area can be recovered). This results in a conservative analysis which should eliminate only those areas where vapor recovery is grossly uneconomical. It was immediately apparent that only the two large Freon users, the component cleaning facility (CCF)(Stream Group G) and the SCAPE suit cleaning facility (Stream Group F), could possibly justify the cost of a vapor recovery unit.

Through further development of the design for the new VAFB SCAPE suit cleaning facility, it was noted that a design similar to the existing KSC facility was highly unlikely. The new VAFB facility will either use a non-Freon based cleaning system (soap and water) or a Freon based cleaning booth with a self-contained system for vapor recovery and recycle. Because of this development, the design for vapor recovery facilities for the SCAPE suit cleaning operation was not pursued any farther.

The only vapor recovery unit which still looked attractive at the completion of the preliminary conceptual design review was for the CCF. The remainder of this section presents the details of that conceptual design.

4.2 Conceptual Design Basis for Vapor Recovery at the CCF

The projected inventory of solvent vapor losses available for recovery at the CCF is given in Table 4-2. These vapors result primarily from the precision cleaning of parts with Freon in the clean room area of the CCF. The estimates of vapor losses per gallon of liquid solvent used in the cleaning process are based on Kennedy Space Center (KSC) data that have been

TABLE 4-1. PRELIMINARY ECONOMICS FOR VAPOR RECOVERY

STREAM GROUP	MAXIMUM RECOVERABLE SOLVENT VAPORS ----FREON------- GAL/YR	$/YR	APPROX. MINIMUM RECOVERY SYSTEM COSTS * INST. CAPITAL COST $	CAPITAL RECOVERY COST $/YR	OPER. & MAINT. COST $/YR	TOTAL ANNUAL COST $/YR	NET SYSTEM SAVINGS $/YR
A	1	9.74	50000	12000	15000	27000	-26990
B	6	58.44	50000	12000	15000	27000	-26942
C	16	155.84	50000	12000	15000	27000	-26844
D	43	418.82	50000	12000	15000	27000	-26581
E	17	165.58	50000	12000	15000	27000	-26834
F	2328	22674.72	50000	12000	15000	27000	-4325
G	10094	98315.56	50000	12000	15000	27000	71316
H	131	1275.94	50000	12000	15000	27000	-25724
I	101	983.74	50000	12000	15000	27000	-26016
J	23	224.02	50000	12000	15000	27000	-26776
K	100	974	50000	12000	15000	27000	-26026

* These figures conservatively assume that all streams within a group can be recovered by a single system, which is usually not practical because many of these streams are spread widely over the base.

TABLE 4-2. SUMMARY OF THE SOLVENT GENERATED BY VAPOR RECOVERY AT THE CCF

YEAR	LAUNCHES	FREON	IC3OH	TOTAL
1986	1	5874	30	5903
1987	2	10006	50	10056
1988	2	10006	50	10056
1989	3	12521	63	12584
1990	4	14375	72	14447
1991	5	15865	80	15945
1992	6	17126	86	17213
1993	7	18229	92	18321
1994	8	19216	97	19313
1995	9	20115	101	20216
TOTAL	47	143334	720	144054
VOLUME %		99.50	0.50	100.00

Note: Low launch rate scenario.
Note: These figures include only solvents from vapor recovery, no waste liquid solvents are included.

modified to reflect the procedures likely to be used at VAFB. The KSC CCF reported Freon vapor losses of 15,000 gallons per year (7500 GPY indoors and 7500 GPY in field cleaning) for activities in support of three shuttle launches. It was assumed that the vapor losses would increase with increasing launch activity, and that the increase would be proportional to increases in the rate of generation of waste liquid solvents from streams G1, G4, and G11 (as presented in Table 2-1). The following assumptions were made in estimating the proportion of the total vapor losses which would be accessible to the vapor recovery system:

1. Since the VAFB CCF will be designed to accomodate the shuttle preparation activities, it is likely that less outdoor cleaning will be done. Accordingly, the indoor losses are estimated to be 90% of the total for VAFB (rather than the 50% for KSC).

2. It is assumed that 95% of all the cleaning done inside the CCF will be done in hoods with segregated ventilation systems which will feed the vapor recovery system.

3. The capture efficiency of the hoods is assumed to be 95%.

4. It is assumed that there will be eight such hoods in Freon cleaning service in the new CCF, two large hoods (5 feet wide by 30 inches high) and six small hoods (3 feet wide by 30 inches high). These hoods are typically designed to give a face velocity of 100 feet/minute when fully open. It is assumed that the normal operating procedure will be to operate the hoods with the front cover 2/3 closed, resulting in a face velocity of 150 feet/minute. These figures are based on a survey of the hoods in use at the Radian chemistry laboratories in Austin, on discussions with industrial hygiene specialists in Radian's Salt Lake City offices, and on calculations of the reasonable ranges for exhaust rates and solvent concentrations leaving the hoods.

5. It is assumed that the losses will occur during a single-shift (8 hour) workday, with 5 workdays per week, and 10 holidays per year. This results in 2000 hours per year of active operation for the vapor recovery unit. The hours of operation are assumed to be independent of the shuttle launch rate.

Given these assumptions, the feed to the vapor recovery unit is calculated to be an air stream of about 4100 scfm with solvent concentrations in the range of 1100 ppmv.

4.3 Review of Vapor Recovery Options

There are many different ways to approach the recovery of solvent vapors, such as absorption in circluating oil, condensation using cooling water, condensation using refrigeration, compression/condensation, and adsorption on a variety of solids. The only processes that have been well demonstrated in this particular type of vapor recovery application are refrigerated condensation and carbon adsorption. Refrigerated condensation can provide economical recovery of concentrated vapors, but with solvent concentrations in the 1100 ppmv range, very low temperatures would be required to achieve any significant recovery of the vapors. The power requirements of the refrigeration system to attain the required low temperatures would make condensation uneconomical. Carbon adsorption is the only reasonable choice for vapor recovery at the VAFB CCF.

4.4 Details of the Conceptual Design for Vapor Recovery

Figure 4-1 presents a schematic flow diagram of the carbon adsorption unit proposed for the CCF. This is a conventional fixed-bed carbon adsorption unit with two beds, one of which would be in adsorption service and one in regeneration service at any given time. Table 4-3 presents some of the design criteria for the carbon adsorption unit.

The installed capital cost of the system designed according to the above criteria is estimated to be $330,000, based on cost correlations presented in the EPA report titled "Organic Chemical Manufacturing Volume 5: Adsorption, Condensation, and Absorption Devices". That figure was updated to mid-1983 dollars based on the Marshall and Stevens Construction Index published in Chemical Engineering magazine.

The operating costs of the vapor recovery unit include utilities (electricity, steam, and cooling water), operating and maintenance labor, maintenance materials, carbon replacement (on a 5 year frequency), taxes, insurance, and general-and-administrative expenses. Table 4-4 presents a breakdown of the operating cost estimates on a yearly basis. The primary estimates are made on the full scale operating expenses for the year 1995, and scaled back to reflect the reduced operating rates in other years. It should be noted that the operating cost estimates presented here for the carbon adsorption unit do not include any incremental operating expenses necessary to purify the recovered solvent. The economic analysis of the combined vapor recovery and solvent purification processes in Section 5 does include all costs associated with both units.

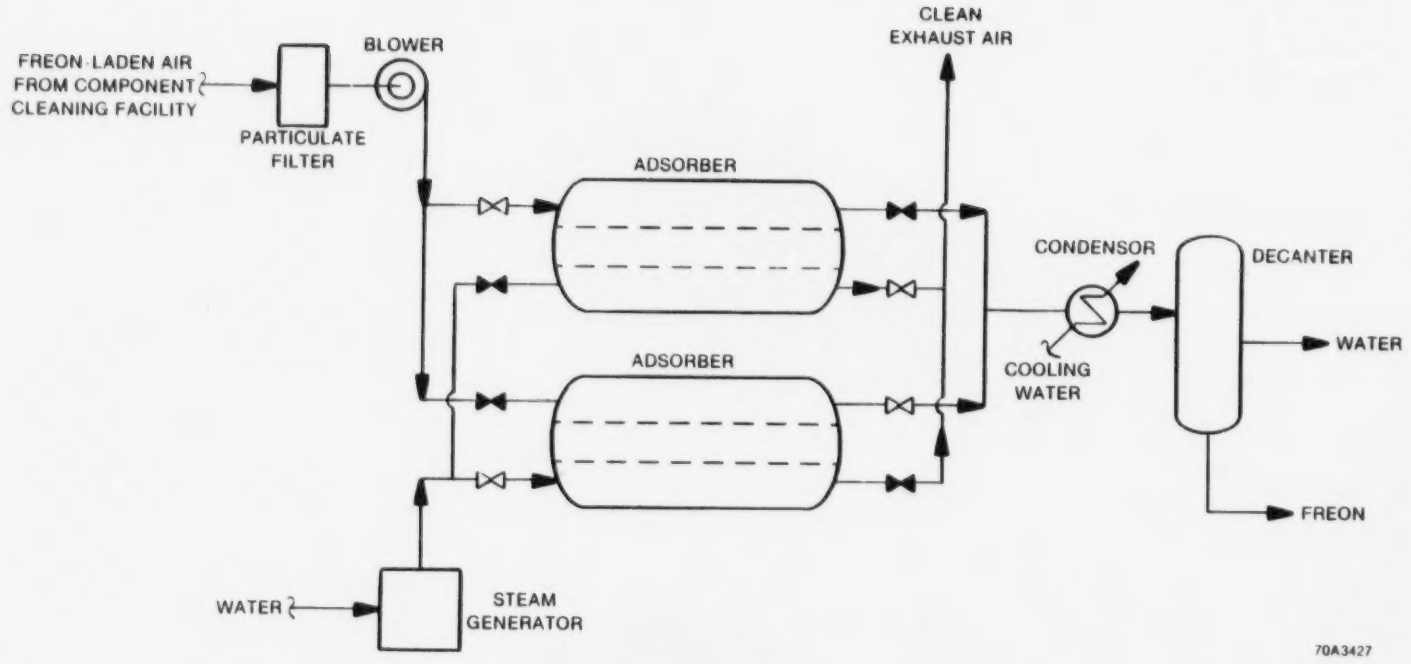

FIGURE 4-1. SIMPLIFIED FLOW DIAGRAM OF THE CARBON ADSORPTION UNIT

TABLE 4-3. DESIGN PARAMETERS FOR THE CARBON ADSORPTION UNIT

Superficial air velocity across the carbon bed	100 ft/min.
Carbon particle size	4x10 mesh
Carbon bulk density	30 lb/cubic foot
Hydrocarbon concentration in exhaust air	12 ppmv
Steam required for regeneration	1.0 lb steam/lb carbon
Air temperature to bed	75 degrees F
Pressure drop across the carbon bed	6.5 in. water/ft. carbon
Carbon life	5 years
Minimum carbon bed depth	1.5 feet
Maximum carbon bed depth	3.0 feet
Blower capacity	130 % of solvent laden air
Cooling water requirements	4.2 gal/lb steam
Cooling water temperature	80 degrees F

TABLE 4-4. SUMMARY OF OPERATING AND MAINTENANCE COSTS
CARBON ADSORPTION UNIT FOR CCF SOLVENT VAPORS

INSTALLED CAPITAL COST= $ 330000 *

YEAR	SOLVENT LOADING GAL/YEAR	OPERATING & MAINT. COSTS $/YR	TAXES+ INSUR.+ G&A $/YR	UTILITY COSTS ELECTRIC $/YR	STEAM $/YR	COOLING WATER $/YR	REPLACE ACTIVATED CARBON $/YR	TOTAL OPERATING AND MAINT. COSTS $/YR
1986	5874	5782	7884	972	5087	429	0	20153
1987	10006	9849	10852	1338	8665	731	0	31436
1988	10006	9849	10852	1338	8665	731	0	31436
1989	12521	12325	12415	1531	10844	914	0	38030
1990	14375	14149	13487	1663	12449	1050	10125	52924
1991	15865	15617	14310	1765	13740	1159	0	46590
1992	17126	16858	14982	1848	14832	1251	0	49771
1993	18229	17944	15554	1918	15787	1331	0	52534
1994	19216	18916	16054	1980	16642	1403	0	54994
1995	20115	19800	16500	2035	17420	1469	10125	67349
TOTAL	143334	141089	132891	16390	124130	10468	20250	445218

* Capital cost correlations based on a two bed system, with 3 foot bed depth, 4082 scfm capacity, and carbon/bed of 4050 pounds. Cost reference:
US EPA, "Organic Chemical Manufacturing, Volume 5: Adsorption, Condensation, and Absorption Devices", EPA-450/3-80-027, ESED, OAQPS, Research Triangle Park, NC, December, 1980.

** Operating costs presented here represent only the cost of operating the carbon adsorption unit. The incremental cost of purifying the recovered solvent is not included here, but is covered in Section 5.

Tables 4-5 through 4-7 present economic analysis data on the estimated ten year life cycle of the vapor recovery unit. Table 4-5 presents an estimate of the solvent recovery credits, based on an estimated 90% recovery efficiency. The 90% value is derived from the 95% recovery of the carbon adsorption unit followed by the 95% recovery of the purification unit. Table 4-6 presents a net present value (NPV) calculation for the vapor recovery unit using a discount factor of 11.75%, which is equivalent to the interest rate paid on long term Treasury Bonds, and using an inflation-excluded basis for the calculations. Table 4-7 presents the results of similar calculations but taking into account a 5% general inflation rate.

There are several conclusions to be drawn from all of this economic data. The carbon adsorption unit appears to offer a small savings (about $87,000) when financed by the sale of Treasury Bonds and with the savings calculated without taking inflation into account. If a general inflation rate of 5 percent is figured into the calculations, then the savings increase to about $222,000. The construction of onsite solvent recovery facilities is, therefore, an excellent hedge against inflation, and one which will generate some savings even through a period of no inflation.

One final point about the vapor recovery unit should be noted, and that is the generation of a wastewater stream consisting of condensed regeneration steam and dissolved organics. That stream would have a maximum operating rate of 4.0 gpm, but since the stream would only occur on an intermittent basis, the total annual generation would only be about 29,000 gallons. The primary contaminant would be isopropanol, which would be present at a concentration of about 315 ppmv. It is likely that traces of other organic species would also be present, but at the sub-ppm level.

TABLE 4-5. SUMMARY OF THE RECOVERY CREDITS

VAPOR RECOVERY AT THE CCF

FREON-113
FRESH SOLVENT VALUE= 9.74$/GAL. *
OFFSITE RECOVERY DEBIT= 0.00$/GAL. **

YEAR	FEED GAL./YR.	RECOVERED SOLVENT GAL./YR.	FRESH SOLVENT VALUE $/YEAR	OFFSITE RECOVERY DEBIT $/YEAR	NET RECOVERY CREDIT $/YEAR
1986	5874	5287	51491	0	51491
1987	10006	9005	87713	0	87713
1988	10006	9005	87713	0	87713
1989	12521	11269	109759	0	109759
1990	14375	12938	126011	0	126011
1991	15865	14279	139073	0	139073
1992	17126	15413	150127	0	150127
1993	18229	16406	159795	0	159795
1994	19216	17294	168447	0	168447
1995	20115	18104	176328	0	176328
TOTAL	143333	129000	1256457	0	1256457

* No Air Force price was currently available for the Freon-113; the $9.74 is a current Air Force contractor's price for Freon-113.

** No offsite recovery debit is necessary for solvents from vapor recovery, since there would have been no waste liquid for offsite recovery in the absence of the vapor recovery unit.

TABLE 4-6. NET PRESENT VALUE CALCULATIONS

INFLATION EXCLUDED BASIS
VAPOR RECOVERY CASE

DISCOUNT FACTOR=11.75 % * NET FREON VALUE=9.74 $/GALLON **

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	330000	-330000
1986	51491	20153	31338	0.89	28043	0	-301957
1987	87713	31436	56277	0.80	45064	0	-256893
1988	87713	31436	56277	0.72	40326	0	-216567
1989	109759	38030	71729	0.64	45995	0	-170572
1990	126011	52924	73087	0.57	41938	0	-128634
1991	139073	46590	92483	0.51	47487	0	-81147
1992	150127	49771	100356	0.46	46111	0	-35036
1993	159795	52534	107261	0.41	44102	0	9067
1994	168447	54994	113453	0.37	41743	0	50810
1995	176328	67349	108979	0.33	35881	0	86691
TOTALS	1256457	445218	811239	NA	416691	330000	86691

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

** The recovery credit of $9.74 results from a fresh Freon price of $9.74. no correction for the loss of the offsite recovery credit is necessary.

Note: The exact return on investment for this case is 16.66 %, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

TABLE 4-7. NET PRESENT VALUE CALCULATIONS

INFLATION INCLUDED BASIS
VAPOR RECOVERY CASE

DISCOUNT FACTOR=11.75% * NET FREON VALUE=9.74 $/GALLON **
GENERAL INFLATION RATE=5.00%

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	330000	-330000
1986	54066	21161	32905	0.89	29445	0	-300555
1987	96703	34658	62045	0.80	49683	0	-250871
1988	101538	36391	65147	0.72	46682	0	-204189
1989	133413	46225	87187	0.64	55907	0	-148282
1990	160826	67546	93280	0.57	53524	0	-94758
1991	186371	62435	123936	0.51	63637	0	-31121
1992	211243	70033	141210	0.46	64883	0	33763
1993	236091	77617	158473	0.41	65159	0	98922
1994	261317	85314	176003	0.37	64758	0	163680
1995	287220	109704	177515	0.33	58447	0	222127
TOTALS	1728788	611085	1117702	NA	552127	330000	222127

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

** The recovery credit of $9.74 results from a fresh Freon price of $9.74. No correction for the loss of the offsite recovery credit is necessary.

Note: The exact return on investment for this case is 22.49 %, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

5.0 COMBINED SOLVENT RECOVERY SYSTEM DESIGN SPECIFICATIONS

The combined solvent recovery system will include a solvent vapor recovery unit for the component cleaning facility and a solvent purification unit which will process selected waste liquid solvents and solvent from vapor recovery. The projected composition of the combined feed to the purification unit is presented in Table 5-1. This section presents the overall economics for the combined solvent recovery system, as well as the design specifications for the recommended equipment.

5.1 Economics of the Combined Solvent Recovery System

The previous two sections have presented the conceptual design and economics of the solvent purification facility and the vapor recovery unit. Each of these elements of the total solvent recovery system had to show an economic justification independently, and that was demonstrated by the positive net present values of these subsystems when discounted at the Treasury Bond rate of 11.75 % (the projected "cost of money" for the Air Force to finance the construction of the solvent recovery facilities). The decision of whether to invest in the solvent recovery system, however, is most appropriately made on the basis of the overall system economics.

Table 5-2 presents a summary of the operating costs of the solvent recovery system. The total operating cost shown in that table is slightly higher than the sum of the operating costs of the vapor recovery system and the purification system as presented independently. The reason for this discrepancy is that the incremental cost of purifying the extra solvent from vapor recovery has been added to this analysis, while it was omitted from the economic analysis for vapor recovery alone. The solvent recovery credits for the overall system, however, are equal to the sum of the credits presented for the two subsystems, so no table has been included that would duplicate that data.

Table 5-3 presents the net present value calculations for the combined solvent recovery system using a discount rate of 11.75 % and excluding the effects of inflation. The resulting NPV of $118,549 represents the savings that can be expected over the 10 year economic life of the proposed project after repaying the principle and interest on the debt incurred to finance the facility, as well as all operating and maintenance costs.

The above savings is expressed in terms of constant-value 1983 dollars, with no allowance for inflation in solvent value, labor rates, or maintenance materials. Table 5-4 presents a similar calculation, but with a five percent general inflation

TABLE 5-1.

SUMMARY OF THE COMBINED FEED TO THE PURIFICATION UNIT

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL	
COMPONENT/LAUNCHES	1	2	2	3	4	5	6	7	8	9	47	VOL.%
	GENERATION RATES IN GALLONS FOR THE PERIOD											
FREON	20150	33507	33507	41844	47466	52620	56963	60914	64506	67823	479302	93.31
IC3OH	1165	2435	2435	2075	501	530	555	579	601	621	11495	2.24
MEK	228	234	234	240	242	248	254	260	266	272	2478	0.48
ME CL	122	122	122	122	122	122	122	122	122	122	1220	0.24
111TCEA	470	476	476	482	158	164	170	176	182	188	2941	0.57
TRICH	1289	1289	1289	1289	79	79	79	79	79	79	5628	1.10
MIBK	4	4	4	4	4	4	4	4	4	4	44	0.01
TOLUENE	37	75	75	112	150	187	225	262	300	337	1760	0.34
ACETONE	61	61	61	61	61	61	61	61	61	61	613	0.12
ETHANOL	4	4	4	4	4	4	4	4	4	4	44	0.01
NAPHTHA	3	5	5	8	11	13	16	18	21	24	124	0.02
METHANOL	812	1820	812	1484	140	140	140	140	140	140	5764	1.12
UNKNOWN	61	61	61	61	61	61	61	61	61	61	610	0.12
WATER	31	31	31	31	31	31	31	31	31	31	311	0.06
INK	0	0	0	0	0	0	0	0	0	0	3	0.00
SOLIDS	4	4	4	4	4	4	4	4	4	4	44	0.01
GREASE	0	0	0	0	0	0	0	0	0	0	3	0.00
DIRT	0	0	0	0	0	0	0	0	0	0	1	0.00
OIL	126	126	126	126	126	126	126	126	126	126	1259	0.25
TOTALS	24569	40255	39247	47949	49160	54396	58816	62844	66589	69899	513644	100.00

NOTE: These figures include both waste liquid solvents and solvents from vapor recovery.

TABLE 5-2. SUMMARY OF OPERATING AND MAINTENANCE COSTS

COMBINED PURIFICATION AND VAPOR RECOVERY UNITS

INSTALLED CAPITAL COST= $1,125,000 *

YEAR	SOLVENT LOADING GAL/YEAR	OPERATING & MAINT. COSTS $/YR	TAXES+ INSUR.+ G&A $/YR	UTILITY COSTS ELECTRIC $/YR	STEAM $/YR	COOLING WATER $/YR	REPLACE ACTIVATED CARBON $/YR	TOTAL OPERATING AND MAINT. COSTS $/YR
1986	24725	23966	30220	9847	6185	647	0	70865
1987	40348	39110	40543	13210	10093	1055	0	104012
1988	38134	36964	39193	12770	9539	997	0	99464
1989	47985	46513	44987	14658	12004	1255	0	119417
1990	49144	47636	45635	14869	12294	1285	10125	131845
1991	54329	52663	48467	15792	13591	1421	0	131933
1992	58699	56899	50770	16542	14684	1535	0	140430
1993	62677	60755	52807	17206	15679	1639	0	148086
1994	66294	64261	54615	17795	16584	1734	0	154988
1995	69636	67500	56250	18328	17420	1821	10125	171444
TOTAL	511972	496268	463486	151018	128074	13388	20250	1272484

* This is the combined cost of the purification unit and the vapor recovery unit. See the individual estimates for the basis of these figures.

TABLE 5-3. NET PRESENT [illegible] CALCULATIONS

INFLATION EXCLUDED [illegible]S
COMBINED PURIFICATION UNIT AND VAPOR RECOVERY UNIT

DISCOUNT FACTOR=11.75 % *

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	1125000	-1125000
1986	157290	70865	86425	0.89	77338	0	-1047662
1987	260707	104012	156695	0.80	125476	0	-922186
1988	260707	99464	161243	0.72	115541	0	-806645
1989	325133	119417	205716	0.64	131910	0	-674735
1990	368794	131845	236949	0.57	135962	0	-538773
1991	408509	131933	276576	0.51	142014	0	-396760
1992	441967	140430	301537	0.46	138550	0	-258209
1993	472337	148086	324251	0.41	133322	0	-124887
1994	499913	154988	344925	0.37	126910	0	2023
1995	525360	171444	353916	0.33	116526	0	118549
TOTALS	3720716	1272484	2448232	NA	1243549	1125000	118549

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

Note: The exact return on investment for this case is 13.76%, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

TABLE 5-4. NET PRESENT VALUE CALCULATIONS

INFLATION INCLUDED BASIS
COMBINED PURIFICATION UNIT AND VAPOR RECOVERY UNIT

DISCOUNT FACTOR=11.75 % * GENERAL INFLATION RATE=5.00 %

YEAR (A)	VALUE OF SOLVENT RECOVERED $/YEAR (B)	ANNUAL OPERATING EXPENSES $/YEAR (C)	ANNUAL CASH FLOW $/YEAR (D)=B-C	DISCOUNT FACTOR,% 11.75 (E)	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR (F)=D*E	CAPITAL EXPENDIT. $/YEAR (G)	CUMULATIVE NET PRESENT VALUE $ SUM OF (G-F)
1985	0	0	0	1.00	0	1125000	-1125000
1986	165154	74408	90746	0.89	81204	0	-1043796
1987	287429	114673	172756	0.80	138337	0	-905458
1988	301801	115142	186659	0.72	133754	0	-771705
1989	395201	145152	250049	0.64	160338	0	-611367
1990	470684	168271	302413	0.57	173525	0	-437842
1991	547441	176803	370639	0.51	190312	0	-247530
1992	621891	197599	424292	0.46	194954	0	-52576
1993	697857	218790	479067	0.41	196977	0	144401
1994	775529	240438	535091	0.37	196879	0	341281
1995	855755	279264	576491	0.33	189809	0	531090
TOTALS	5118745	1730541	3388204	NA	1656090	1125000	531090

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

Note: The exact return on investment for this case is 19.45%, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

rate taken into account, which results in an NPV of $531,090. The consideration of inflation improves the NPV of the project because of two factors: 1) the effect of inflation on the recovered solvent credits outweighs the effect on the operating and maintenance costs for this case; and 2) the project is assumed to be financed at a fixed rate. Since the solvent credits are greater than the operating costs of the recovery system in the inflation excluded case, then any scenario which assumes a general rate of inflation (one which affects all prices to the same degree) will increase the net savings of the system. It is also important that the funding for the project would be based on fixed rate financing (such as the 11.75% current rate on Treasury Bonds), since the repayment of a fixed rate loan with inflated dollars is a distinct advantage to the economics of the project. If this were an industrial project with financing by retained earnings, then it would be appropriate to increase the discount factor by the anticipated rate of inflation, which effectively negates any improvement in the NPV. The use of a five percent figure in Table 5-4 is not intended to be a prediction of the probable general inflation rate, but only to illustrate the effect of inflation on the economics of the project. Figure 5-1 presents a graphic analysis of the relationship between the NPV of the proposed solvent recovery project and a range of values for the general inflation rate. The important point is that the solvent recovery project is attractive when analyzed on an inflation-excluded basis, and even more so if a positive general inflation rate is assumed.

5.2 Combined Solvent Recovery System Design Specifications

Since the economics indicate that it should be attractive to implement, it is appropriate to present the design specifications for the proposed system. These specifications serve to better describe the facilities under consideration, to explain the cost basis, and to provide guidance in the preparation of bid specifications should the project be taken to completion.

Table 5-5 presents the design specifications for the purification unit, while Table 5-6 presents the specifications for the vapor recovery unit. The design of the separations equipment in the purification facility is based upon simulation of the processes using ASPEN (Advanced System for Process ENgineering), which was developed at MIT under the sponsorship of the US DOE in partnership with 55 private companies. The design of the carbon adsorption unit is based on a compilation of design factors gathered through US EPA sponsored research, independent Radian testing, and data from vendors of carbon-based systems.

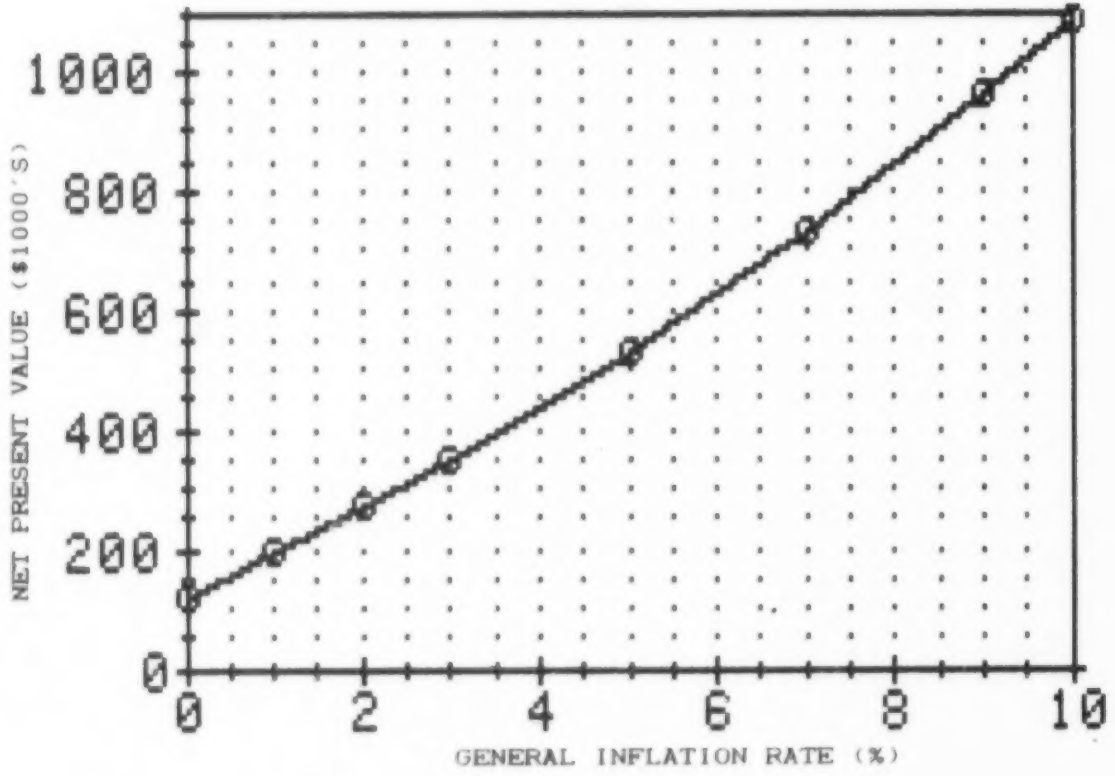

FIGURE 5-1. EFFECT OF GENERAL INFLATION ON NET PRESENT VALUE-COMBINED VAPOR RECOVERY AND PURIFICATION CASE

TABLE 5-5. DESIGN SPECIFICATIONS FOR MAJOR EQUIPMENT - PURIFICATION UNIT

ITEM	SPECIFICATIONS *
Feed mix tanks (2)	3500 gallons each--cylindrical tanks Diameter=7 ft. and height=12 ft. Cone roof--atmospheric pressure-- Safety relief valves--+20 to -10 in. water. Welded construction--carbon steel.
Feed pump	Centrifugal pump--electric motor driver-- Rated at 20 gallons/hour at a discharge pressure of 50 psia
Water wash column	Pulsed-flow, counter-current contactor Cylindrical vessel--baffled internals Diameter=0.5 ft. and height=20 ft.
Light ends column	Cylindrical column--hemispherical heads-- Feed capacity=20 gal./hr. nominal Diameter=8 in. and height=50 ft. High efficiency packing internals--HETP=16 in. 35 theoretical plates--feed to 12th from top-- Solenoid reflux splitter--reflux ratio=37-- Electrically heated reboiler=73 MBtu/hr.-- Cooling water condenser=72 MBtu/hr. Operating pres=25 psia--design max=100 psia-- Overhead temp=127 degrees F Bottom temperature=153 degrees F

* All materials are to be specified as 316 stainless steel unless specifically noted otherwise.

TABLE 5-5. DESIGN SPECIFICATIONS FOR THE PURIFICATION UNIT(Cont'd.)

ITEM	SPECIFICATIONS *
Freon product column	Cylindrical column--hemispherical heads-- Feed capacity=18 gal./hr. nominal Diameter=6 in. and height=31 ft. High efficiency packing internals--HETP=16 in. 20 theoretical plates--feed to 7th from top-- Solenoid reflux splitter--reflux ratio=4.3-- Electrically heated reboiler=43 MBtu/hr.-- Cooling water condenser=55 MBtu/hr. Operating pres=20 psia--design max=100 psia-- Overhead temperature=129 degrees F Bottom temperature=194 degrees F
Freon product cooler	Double-pipe heat exchanger Hot side in--Freon at 129 degrees F Hot side out--Freon at 90 degrees F Cold side in--Cooling water at 80 degrees F Cold side out--Cooling water at 100 degrees F Inside pipe--1 in. OD Outside pipe--2 in. OD Exchanger length--12 feet

* All materials are to be specified as 316 stainless steel unless specifically noted otherwise.

TABLE 5-5. DESIGN SPECIFICATIONS FOR THE PURIFICATION UNIT(Cont'd.)

ITEM	SPECIFICATIONS *
Decanter	Cylindrical vessel--hemispherical heads Vertically mounted Diameter=1.5 ft.--Length=4.0 ft. Interior overflow baffle Level controller and interface controller
Molecular sieve driers	2 cylindrical vessels--horizontally mounted Diameter=1.5 ft.--Length=4 ft. Bed depth=0.5 ft.--bed volume=1.5 cu.ft. 100 lbs. of Union Carbide type 4A-XH-6 or similar adsorbent.
Filters	Two-stage filtration unit First stage--sintered steel element with backflush capabilities-- Second stage--membrane filter with removable element good down to 2 microns.
Quality control tanks	2 cylindrical vessels--400 gallons each-- Diameter=3.5 ft.--height=6 ft. Materials--Carbon Steel

* All materials are to be specified as 316 stainless steel unless specifically noted otherwise.

TABLE 5-5. DESIGN SPECIFICATIONS FOR THE PURIFICATION UNIT(Cont'd.)

ITEM	SPECIFICATIONS *
Freon product tanks	2 cylindrical tanks with cone roofs-- 5000 gallons capacity each Diameter=8 ft.--height=14 ft. One tank kept full (backup supply for 6 weeks) One tank used to receive/disburse product Design pressure--atmospheric Safety relief valves--+20 to -10 in. water
Light solvent waste tank	Cylindrical pressure vessel 250 gallon capacity Diameter=3 ft.--length=5 ft. Working pressure=20 psia Design maximum pressure=100 psia.
Heavy solvent waste tank	Cylindrical tank with cone roof 500 gallon capacity Diameter=3.5 ft.--height=6.5 ft. Working pressure--atmospheric Safety relief valves--+20 to -10 in. water Materials--Carbon Steel
Instrumentation and controls	Fully automatic microprocessor control with manual override capability-- Sensor/indicator/recorders for-- temperature profiles pressure profiles flow rates tank levels product compositions Designed for minimum operator intervention.

* All materials are to be specified as 316 stainless steel unless specifically noted otherwise.

TABLE 5-6. DESIGN SPECIFICATIONS FOR MAJOR EQUIPMENT - CARBON ADSORPTION UNIT

ITEM	SPECIFICATIONS
Adsorber vessels	2 vessels--cylindrical--5 ft. diameter and 9 ft. long--hemispherical heads--mounted horizontally--316 stainless steel*
Carbon beds	2 beds--4050 lb. carbon per bed
Main blower	Electric-driven centrifugal fan--20 Hp--capacity=4100 scfm--head=20 in. water
Cooling/drying blower	Electric-driven centrifugal fan--8 Hp--capacity=1350 scfm--head=20 in. water
Inlet particulate filter	Removable paper cartridge filter--pressure drop=5 in. water maximum
Condenser	Shell-and-tube heat exchanger--area=155 square feet--U value=100 btu/hr/sf/degree
Decanter	Cylindrical vessel--hemispherical heads--diameter=4 ft.--length=10 ft.

* All materials are to be specified as 316 stainless steel.

TABLE 5-6. DESIGN SPECIFICATIONS FOR THE CARBON ADSORPTION UNIT(Cont'd.)

ITEM	SPECIFICATIONS
Steam generator	Electrically heated packaged boiler-- maximum capacity=3000 lb/hour steam pressure=25 psia
Instrumentation and controls	Flow measurement--solvent laden air cooling/drying air boiler feed water decanter water decanted solvent Temperatures------inlet air exhaust air condenser outlet carbon beds Pressures---------inlet air blower suction blower discharge bed inlets bed outlets produced steam Concentrations----inlet air exhaust air bed outlets Sequencing controller and remote-operated valves to allow unattended adsorption-regeneration cycling on a timed basis.

* All materials are to be specified as 316 stainless steel.

5.3 Combined System Economics with a Reduced Launch Rate

The latest available information (April 1984) indicates that the maximum annual launch rate may be as low as four instead of nine. Although this information arrived too late to be included in the design and economic calculations for this study, this section has been added to the final report to estimate the effects of these changes on the system economics. These economic estimates are based on the following assumptions:

1) no changes to the solvent recovery system design,
2) system construction in 1988, start-up in 1989,
3) launch rates of 3/year in 1989 and 4/year thereafter,
4) a general inflation rate of 5 percent, and
5) a discount rate of 11.75 percent.

These assumptions are all very conservative in nature (except for the inflation rate) and should result in a slight underestimation of the economic attractiveness of the solvent recovery project. Table 5-7 presents the net present value calculation for this case, while Figure 5-2 presents the estimated relationship between return on investment and the rate of recovered solvent. Despite the fact that the solvent recovery rate is only about 70% of the maximum for the base case, this case yields a better net present value. The main reason for this is the delay in construction of the facility. This eliminates the first three years of marginal operations for the base case and results in a more uniform cash flow over the project life. Under this set of assumptions, the solvent recovery rate could be 33% less and still meet the minimum required return on investment (see Figure 5-2).

TABLE 5-7. NET PRESENT VALUE CALCULATIONS

REDUCED LAUNCH RATE AND DELAYED CONSTRUCTION CASE
INFLATION INCLUDED BASIS
COMBINED PURIFICATION UNIT AND VAPOR RECOVERY UNIT

DISCOUNT FACTOR=11.75 % * GENERAL INFLATION RATE=5.00 %

YEAR	VALUE OF SOLVENT RECOVERED $/YEAR	ANNUAL OPERATING EXPENSES $/YEAR	ANNUAL CASH FLOW $/YEAR	DISCOUNT FACTOR 11.75 %	NET ANNUAL DISCOUNTED CASH FLOW $/YEAR	CAPITAL EXPENDIT. $/YEAR	CUMULATIVE NET PRESENT VALUE $
1988	0	0	0	1.00	0	1367445	-1367445
1989	414961	152410	262551	0.89	234945	0	-1132499
1990	494219	176685	317534	0.80	254270	0	-878229
1991	518930	185519	333411	0.72	238912	0	-639317
1992	544877	194795	350082	0.64	224481	0	-414837
1993	572121	204535	367586	0.57	210922	0	-203915
1994	600727	214762	385965	0.51	198181	0	-5734
1995	630763	225500	405263	0.46	186211	0	180477
1996	662301	236775	425526	0.41	174963	0	355440
1997	695416	248613	446803	0.37	164395	0	519835
1998	730187	261044	469143	0.33	154465	0	674300
TOTALS	5864501	2100637	3763864	NA	2041744	1367445	674300

* The discount factor was set at the interest rate for long term Treasury Bonds, which was 11.75 % according to the Wall Street Journal of December 13,1983.

Note: The exact return on investment for this case is 21.63%, which was determined by repetitive calculations of the NPV using different discount factors, until an NPV of zero was obtained.

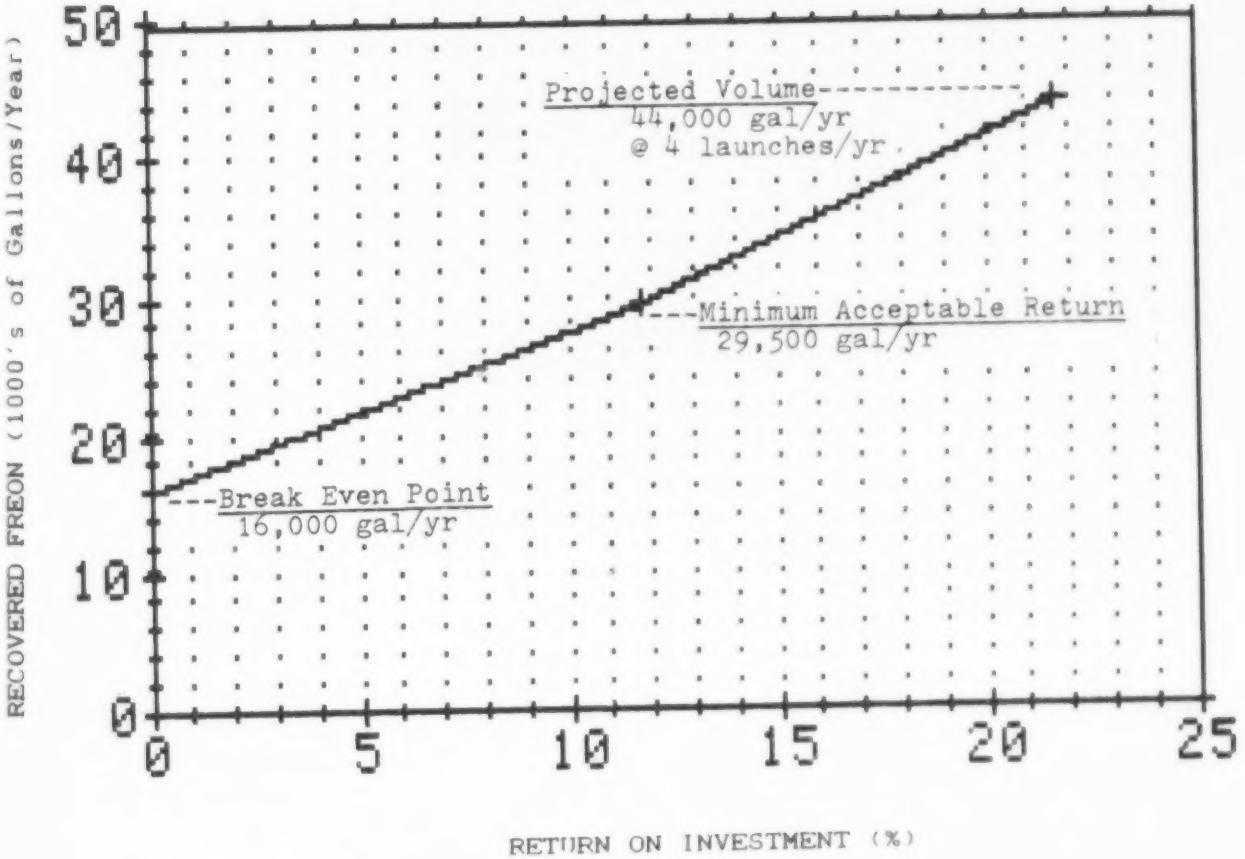

FIGURE 5-2. EFFECT OF SOLVENT RECOVERY RATE ON SYSTEM ECONOMICS-COMBINED VAPOR RECOVERY AND PURIFICATION CASE

6.0 SITE LOCATION AND SOLVENT LOGISTICS

This section presents recommendations for specific locations of each element of the solvent recovery system, as well as a discussion of the logistics of moving waste solvent to the purification facility and reclaimed solvent back to the use areas. There are two main components of the solvent recovery system : the vapor recovery unit and the liquid solvent purification unit. The vapor recovery unit must be located at the future site of the Component Cleaning Facility (CCF), because of the high cost of compressing the vapors and transporting them to any other area. There are two possibilities for the location of the solvent purification unit: 1) adjacent to the CCF, or 2) adjacent to the hazardous waste accumulation point near the planned site of the Orbiter Maintenance and Checkout Facility (OMCF). This section discusses the advantages and disadvantages of these two locations, and supports the choice of the CCF location.

The second subsection discusses the movement of waste liquid solvents from the various use areas to the purification unit. Particular attention is paid to taking advantage of the existing transportation system that is used in conjunction with the Hazardous Waste Management Plan for VAFB. The addition of a bulk Freon system for the CCF is also recommended.

The final subsection discusses the distribution of reclaimed solvent back to the use areas. The recommended procedures for containerizing the reclaimed solvent are also covered. The bulk system recommended for the CCF can also greatly reduce the demands for container handling.

6.1 RECOMMENDED SITE LOCATION

The vapor recovery unit is dedicated to the adsorption and recovery of solvent vapors from the component cleaning facility (CCF) and must be located adjacent to (or inside of) the CCF. The recommended location for the solvent purification unit is also adjacent to the CCF, and the remainder of this section presents the rationale for that recommendation.

The primary criteria for selection of the location for the solvent purification unit include:

1. Proximity to major use areas
2. Proximity to hazardous waste accumulation points
3. Manpower requirements
4. Physical requirements.

These criteria are listed approximately in order of their importance in determining the optimum location.

6.1.1 Proximity to Major Use Areas

The spatial distribution of the proposed STS facilities is illustrated in Figures 6-1 and 6-2, representing the north and south areas of VAFB, respectively. The solvent use and waste solvent generation points are represented by capital letters (enclosed in open triangles) that correspond to:

A	Orbiter Maintenance
B	Launch Pad
C	SRB Refurbishment and Subassembly
D	SRB Retrieval (not shown--Port Hueneme)
E	External Tank Processing
F	SCAPE Suit Maintenance (not shown--location not yet determined)
G	Component Cleaning (existing site shown)
H	Miscellaneous Shuttle Support Operations.
I	Miscellaneous Non-Shuttle Support Operations
J	Space Launch Complex 2 (SLC2), Delta
K	Atlas and Titan Launch Operations

No specific site is noted for stream groups H or I because they are composed of a large number of small, widely dispersed sources.

The CCF (stream group G) is by far the largest source of waste solvent, contributing more than 90% of the total waste solvent load. It would obviously be advantageous to locate the solvent purification facility at the site of the CCF, because of the great reduction in the cost of labeling, transportation, and handling of both waste and reclaimed solvent. This location would also allow for bulk handling of Freon-113 used at the CCF, thus avoiding the labor cost and personnel exposure of containerizing most of the reclaimed solvent.

6.1.2 Proximity to Hazardous Waste Accumulation Points

The VAFB Hazardous Waste Management Plan has established two hazardous waste accumulation points and a hazardous waste storage facility on VAFB. These points are marked on the maps as AP1, AP2, and HWSF, respectively. Since the plan calls for all hazardous waste to be transported from the various use areas to one of the two accumulation points prior to determining the final disposition, the collection of waste solvent for the purification unit would be simplified by locating it adjacent to one of the accumulation points. The wastes may be held at the accumulation points for a maximum of 90 days, which would provide ample time to collect the recoverable solvent waste, purify it, and return the still bottoms and any other associated

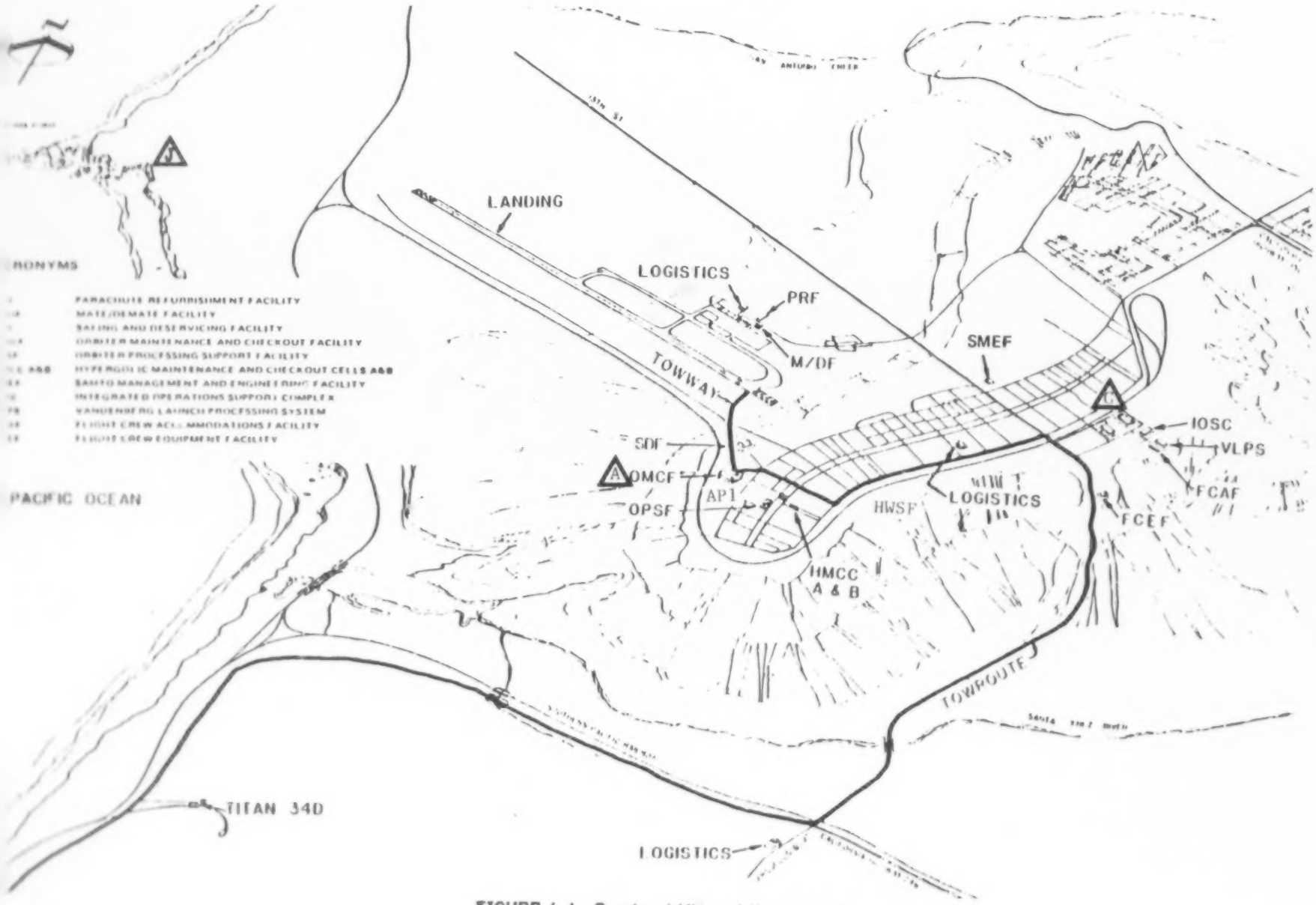

FIGURE 6-1. Overhead View of North VAFB

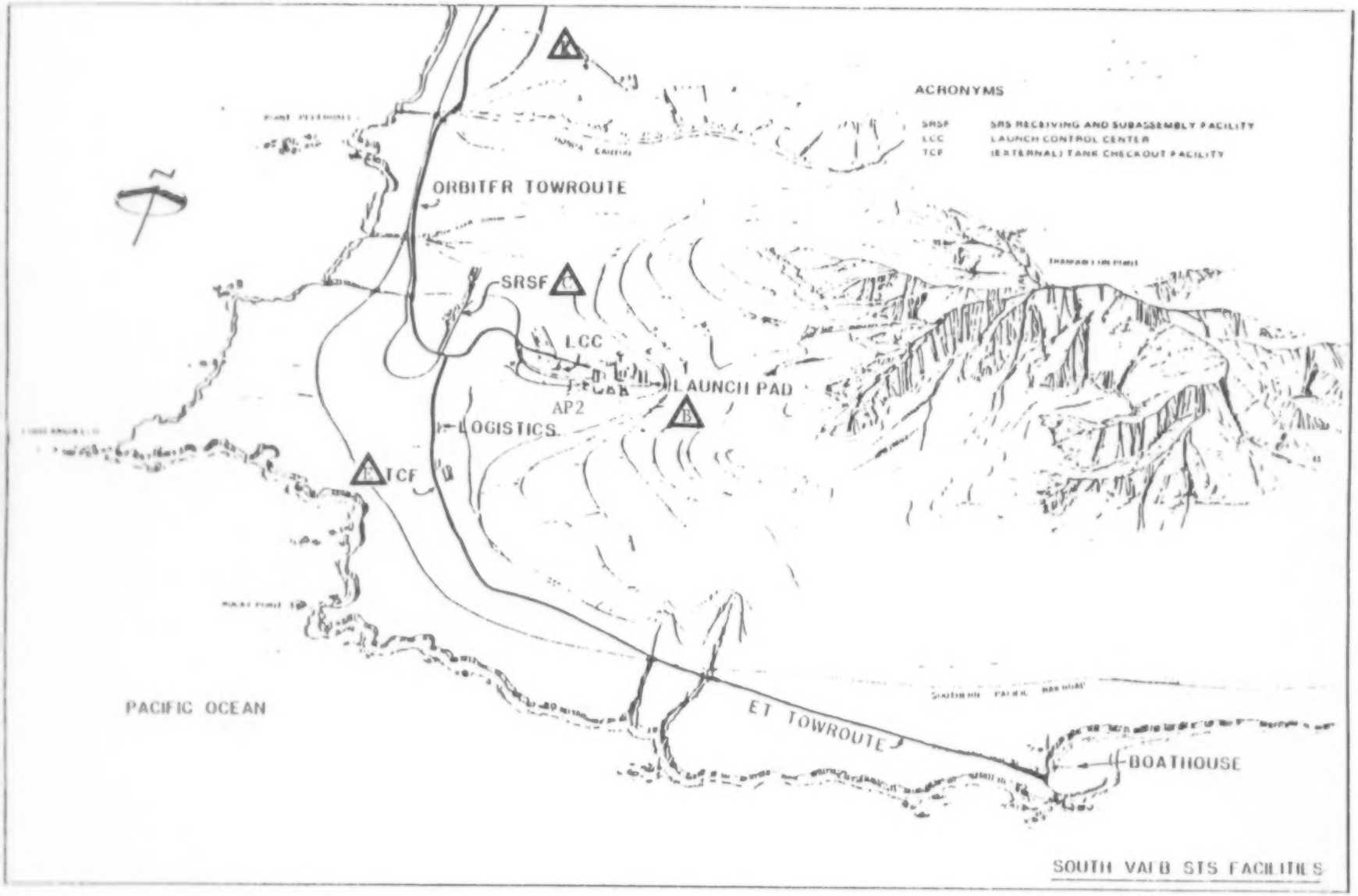

FIGURE 6-2. Overhead View of South VAFB

waste products. If it were decided to locate the purification facility adjacent to one of the accumulation points, the North Vandenberg accumulation point would be preferable because the greater volume of solvent waste (that generated by the CCF and OMCF) would be routed through that point. The NVAFB accumulation point is also in closer proximity to other support facilities.

6.1.3 Manpower Requirements

The third criteria for selecting the location of the purification unit is the availability of manpower at the site. It is estimated that the purification facility will require about half-time coverage for one person. If the purification unit is located in a relatively isolated spot, then it would be impractical for one person to combine the duties of the purification operator with duties at some other site. The site adjacent to the CCF is ideal in this respect, since the purification operator could share duties with the vapor recovery unit and/or the component cleaning operations.

6.1.4 Physical Requirements

The final consideration in selecting a site for the purification unit are the physical requirements of the facility. These physical requirements would include adequate sheltered space and the availability of electric power and cooling water. An ideal type of shelter would be a semi-enclosed area, with two solid walls, two open walls, and a double-gable-vented roof (see Figure 6-3). This type of enclosure could be easily and inexpensively attached to an existing or proposed structure, and provides ample protection from the elements while insuring adequate ventilation for worker health and safety. The width of this enclosure would probably be the same as the CCF, and the additional length would be in the range of 25 to 35 feet. The effective height of the enclosure would have to be 55 to 65 feet to accomodate the light ends column, but this could be reduced by setting the column foundation below grade. The co-location of the vapor recovery unit and the purification unit also allows them to share any packaged utilities that might be needed (such as a small steam boiler or a cooling tower).

6.1.5 Recommended Location

Based on all the above criteria, the site adjacent to the CCF is recommended for both the purification unit and the vapor recovery unit. It is recognized that the present site of the CCF may or may not be the site used when full launch operations are commenced. It is recommended that the solvent recovery facilities be located adjacent to the CCF's ultimate site, whether

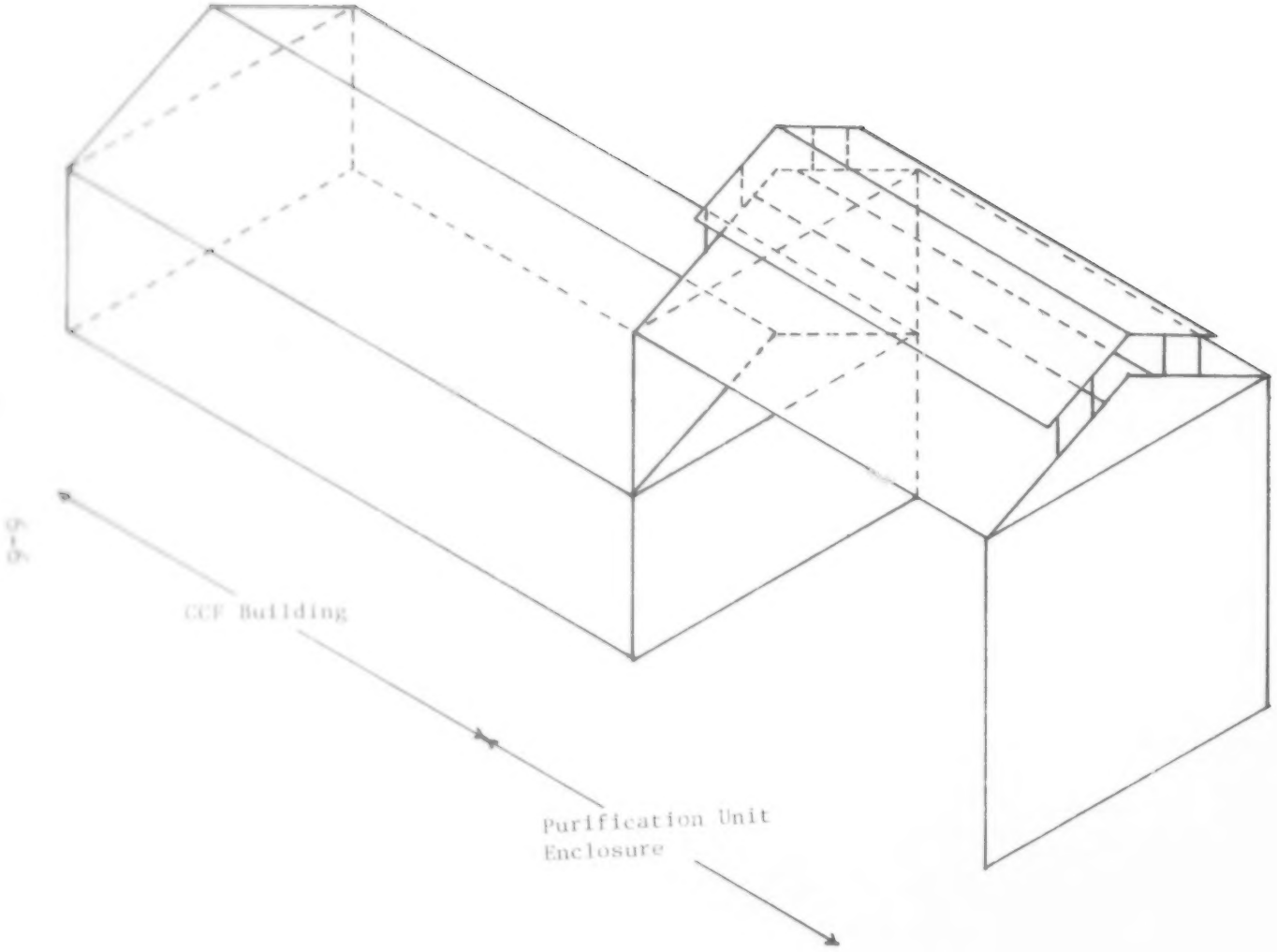

FIGURE 6-3. Isometric Drawing of the Suggested Enclosure

that is the current site or a new site. The primary driving force behind that recommendation is the ability to use a bulk Freon-113 system at the CCF and the ability to share manpower and utilities between the purification unit, the vapor recovery unit, and the CCF.

6.2 Logistics of Solvent Collection/Distribution

Waste solvents are generated in the 11 stream groups identified in the previous subsection, but the distribution of the waste solvents is even wider than that would indicate, because several stream groups include many small scattered sources. The distribution of users of fresh solvents is similarly wide. This subsection deals with the procedures necessary to efficiently collect solvent wastes and redistribute reclaimed solvents.

6.2.1 Spent Solvent Collection

The effort required to collect the waste solvents from these scattered sources, however, can be greatly reduced by taking advantage of the proposed VAFB Hazardous Waste Management Plan (HWMP). The HWMP plan calls for the designation of a an Originator Hazardous Waste Manager (OHWM) and a Collection Point Supervisor (CPS) for each facility who are responsible for carrying out the provisions of the plan. Those provisions specify that each waste solvent stream be analyzed to determine its chemical composition, packaged in a manner consistent with safe storage and transportation, and labeled clearly to identify the waste. The OHWM is also responsible for preparing a Turn-In Document which serves as a manifest to trace the intra-base movement of the waste. Before actually shipping the waste, the Defense Property Disposal Office (DPDO) is notified of the pending shipment and will come out to inspect the containerized waste. The OHWM then contacts the 4392 AEROSG/DEV in writing to schedule the pick-up and transportation of the waste to the accumulation point or the storage facility.

There are two possible ways in which the HWMP and the solvent recovery efforts could be integrated. The first would be to simply pick up containerized waste solvents from the hazardous waste accumulation points and/or the storage facility, separate the recoverable Freon, and return the light solvent waste and the Freon product column bottoms to the hazardous waste storage facility. The other option would be to notify the OHWM at each affected facility that generates a recoverable waste solvent stream and have them arrange for shipment directly to the solvent purification unit. The waste streams suitable for solvent recovery were tentatively identified in the Section 3, but the final selection will not be confirmed until most of the shuttle facilities have been built and the exact volume and

composition of their wastes is known. The latter approach seems to be the most efficient alternative in terms of the number of times any given waste must be moved, but it does involve a larger group of people and place more emphasis on good communication and coordination. Although either plan should work, the approach of identifying the recoverable solvent streams and having them shipped directly to the purification unit is recommended. This should not only reduce the manpower required to search through all the wastes at the accumulation points or the storage area, but should establish an important line of communication between the waste generating facilities and the purification unit. This line of communication could lead to the identification of other recoverable solvent streams or in a small change in the operations which would improve the suitability of the waste solvent for purification. If several different contractors and the Air Force are all sending waste solvents to the purification facility, this direct shipment approach would provide tighter control of the solvent inventories so that each operator could be accurately credited for his recovered solvent.

The above procedures would apply to all use areas except the Component Cleaning Facility (CCF), where it is proposed that a bulk Freon-113 system be installed. That system would include large storage tanks for both waste and fresh/reclaimed solvent. A closed piped system would be provided to distribute fresh solvent to the appropriate cleaning stations within the CCF and to return waste solvent. This bulk solvent system would avoid much of the labor cost and personnel exposure of containerizing and distributing the Freon-113 for the CCF, which represents the bulk of all the projected solvent usage.

Once drums of waste solvent from other use areas arrive at the purification unit, they would be inspected to insure that the waste was indeed appropriate for charging to the unit. A list of waste characterisics which might make the separation more difficult (such as detergents which could cause foaming or acids which could make it difficult to meet the acid number specification) would be provided to the operators to aid them in this determination. The drums would then be moved to a pumping rack near the feed mix tank using either a fork lift or a hand-truck/drum cradle. The waste solvent would be pumped from the drums to the feed mix tank using explosion-proof electric drum pumps. The pumps would be disconnected after losing suction, and the drums inverted over a catch-basin to drain out the last recoverable solvent. The catch-basin would be equipped with a U-tube trap to minimize evaporative losses and would be pumped out to the feed mix tank as needed. The empty waste solvent drums would be sealed, re-labeled, and transported to DPDO for sale or recycling.

There will be a few hazardous waste streams remaining after the recoverable solvents have been removed. The largest volume of these residual wastes will be the bottoms product from the Freon product column (still bottoms). There may also be a variety of other waste materials, including a light solvent waste stream, filter back-flush waste, waste filter cartridges, storage tank bottoms sediment, etc. These materials will be generated either intermittently or at relatively low rates, and will be disposed along with the still bottoms when practical. These materials will be loaded into some of the drums used to deliver waste solvent to the purification unit using screw-driven pumps which can handle relatively high solids concentrations. These drums will have to be re-labeled to denote the characteristics of the waste they contain, and then handled like any other waste under the HWMP.

6.2.2 RECLAIMED SOLVENT DISTRIBUTION

Most of the Freon-113 reclaimed by the solvent purification unit will be reused preferentially at the component cleaning facility (CCF), and will be handled by the bulk system proposed for that facility. Any reclaimed Freon-113 in excess of the CCF requirements will be drummed for distribution to the other use areas. The solvent inventory and handling procedures will be structured in such a way that proper credit for waste solvents contributed and reclaimed solvents used by the Air Force and/or contractors can be determined. The inventory of fresh and reclaimed solvents should be maintained at relatively high levels to insure that any downtime or operating problems on the solvent recovery system could never impact the launch preparation process. This subsection discusses the details of these procedures.

The operation of the bulk Freon-113 system proposed for the CCF is very straight-forward. A fresh/reclaimed Freon tank would be equipped with a pump and connected to a closed-pipe distribution system with outlets at each cleaning staion in the CCF. The drains from these cleaning stations would be piped back to a solvent holding tank. At regular intervals, the solvent holding tank would be tested for contamination; if the tests indicated no problem, then the solvent would be recycled to the fresh/reclaimed Freon tank. If significant degradation of the solvent quality were noted, however, then the solvent from the holding tank would be pumped to the feed mix tank of the purification unit. Both the fresh/reclaimed solvent tank and the solvent holding tank would be dedicated to the CCF, and would be independent of the solvent recovery unit.

The solvent purification unit is designed to recover about 95% of the Freon in the waste solvent feed. Coincidentally, about 95% of the Freon in the waste solvent feed is contributed by the CCF (either as a waste liquid or as solvent from vapor recovery). With the operation in a normal state of balance, therefore, the reclaimed solvent production should just satisfy the CCF requirements for Freon with little, if any, excess. Any shortfall between the reclaimed solvent available and the fresh solvent needs of the CCF will be filled by purchasing fresh Freon through normal channels. Alternatively, any excess reclaimed Freon will be pumped from the product tank at the solvent purification unit to fresh drums and delivered to the central VAFB purchased material distribution point. Since the reclaimed solvent must meet the military specifications for virgin Type I Freon, the reclaimed solvent can be treated interchangeably with virgin solvent, either in the bulk system at the CCF or after it has been drummed and properly labeled. The various use areas can then requisition the solvent as needed and will be supplied with either virgin or reclaimed solvent, depending on the inventory at the time of the requisition.

The system for accounting for waste solvents contributed and reclaimed solvents used will require a careful inventory of the solvent tanks and of the drummed solvents received and dispatched. The four main solvent tanks (the purification unit feed mix and product tanks and the CCF fresh and holding Freon tanks) will have to be gauged twice per shift, as well as before and after any drummed solvent activity. The Turn-in-Documents will provide an accurate record of the waste solvents received, and a similar record-keeping system will have to be developed for the reclaimed solvent disbursed. From these records, it will be possible to prepare a monthly statement of the solvents received/disbursed to and from each separate account. The simplest system for compensating the contributors of recoverable solvent wastes would be to return a proportional volume of reclaimed solvent, but the logistics of returning fractional drums of reclaimed solvents directly to the contributors would be quite cumbersome. A more workable system would be to determine a value for each shipment of waste solvent received based on the volume and the compositon. Each contributor would then be compensated for the waste solvent directly, and could use that money to partially offset the cost of replacement solvents purchased.

Reliability is a key design factor in every system involved in the shuttle preparation activities. That reliability is often provided by redundant systems and automatic switching to the back-up system in case of any trouble with the primary system. The solvent purification facilities are only indirectly involved in shuttle preparation and, therfore, do not require

this type of a back-up system. The required reliability of solvent supplies can be provided by maintaining a substantial fresh/reclaimed solvent inventory. Such an inventory should be sufficient to satisfy all solvent needs during a six week downtime on the solvent recovery unit. Even greater long term reliability can be assured by maintaining contracts with fresh solvent suppliers, which could be activated in case of longer downtimes. The combination of a large onsite inventory and the maintenance of fresh solvent supply lines should provide a high level of reliability in support of shuttle preparation activities.